7. Propulsion Materials

Advanced materials are essential for boosting the fuel economy of modern automobiles while maintaining safety and performance.

Propulsion materials enable higher efficiencies in propulsion systems of all types. For example, many combustion engine components require advanced propulsion materials so they can withstand the high pressures and temperatures of high-efficiency combustion regimes. Similarly, novel propulsion materials may be able to replace the current expensive materials in electric motors and drivetrain components, thus lowering the cost of electric-drive vehicles.

Using lightweight components and high-efficiency engines enabled by advanced materials in one quarter of the U.S. fleet could save more than 5 billion gallons of fuel annually by 2030

The U.S. Department of Energy (DOE) Vehicle Technologies Office (V O) collaborates with industry to improve materials that will increase vehicle efficiency while meeting consumer and industry expectations. It does this through work on both Lightweight Materials and Propulsion Materials. In the case of Propulsion Materials, VTO works closely with other VTO subprogram technology areas to identify and meet requirements for materials needed to develop cost-effective, highly efficient, and environmentally friendly next-generation heavy and light duty powertrains.

Research and development (R&D) is done in collaboration with industry, national laboratories, and universities. The VTO contributes to the Materials Genome Initiative, a federal interagency effort to support Integrated Computational Materials Engineering. It also works through government/industry partnerships:

- The United States Driving Research and Innovation for Vehicle Efficiency and Ene gy sustainability (U.S. DRIVE) Partnership focusing on light-duty vehicles;
- The 21st Century Truck Partnership, focusing on heavy-duty (HD) vehicles; and
- The U.S. Automotive Materials Partnership (USAMP).

The Propulsion Materials (PM) subprogram's major R&D goal is to develop high performance cost-effective materials that solve key challenges that currently limit the performance of propulsion systems (high-efficiency engines and electric drive, and compatibility with alternative fuels).

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2016 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, et

Overview of VTO Material Technologies: Jerry Gibbs (U.S. Department of Energy) - pm000

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer replied yes, stating there was a well-rounded portfolio addressing many areas of materials research focused on expediting the process of moving innovative materials to the marketplace. The reviewer stated that the combination of improving lightweight materials that increase the tolerance of the engine to higher temperatures and pressures and combustion strategies to achieve greater efficiency and the resulting need of low-temperature aftertreatment is very appropriate.

Reviewer 2:

The reviewer answered yes, remarking it was very clearly structured and the content is accurately conveyed.

Reviewer 3:

The reviewer replied yes, that a nice overview was given, with both high-level points and some detail on each area and why it was included. The reviewer concluded that there is an overall strategy uniting the program elements together.

Reviewer 4:

The reviewer replied yes to this question.

Reviewer 5:

The reviewer stated that the program area and overall strategy was sufficiently covered. This included the roadmap and materials requirements for powertrain components, as well as both current limitations and anticipated properties out until 2050. The reviewer commented that one of the innovative claims for this program is that advances in materials for current internal combustion engines, transmission and exhaust components will improve the materials available for other propulsion systems (such as electric) because of the extreme environments and approaches to material design.

Reviewer 6:

The reviewer replied yes, the scope was clearly presented. However, this reviewer does not understand the decrease in funding that the program is seeing given the obvious need for increased materials capabilities to support efficiency requirements for internal combustion engines going forward. The reviewer claimed the reality is that the hydrogen economy is not the future, and for the foreseeable future (say to 2030), the answer will remain the internal combustion engine. The reviewer also observed that increasing efficiency of internal combustion using currently available materials has been optimized, and little changes are available within that space. The reviewer concluded that the obvious answer is that the properties of the materials associated with the combustion event must be changed (temperatures and strength limits) to create a new space for increased efficienc .

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:

The reviewer offered that in a normal situation, the proper materials research balance requires significantly more long-term research as it is at least a second tier to a product. However, the reviewer stated that the program leader has successfully used materials processing to fill in the shorter term research and is doing a great job of continuing to create wins for the program. Praising this is as a novel and creative way to continue to create commercial wins for the program, this reviewer is impressed with this insight.

Reviewer 2:

The reviewer remarked that the balance between near-, mid-, and long-term elements is sufficient, adding that the program has some immediate goals for materials to push the boundary of current material properties as well as to evaluate the knowledge gaps in computational material programs. The reviewer observed that these results enable the mid-term programs to collaborate with the development of solutions to fill these gaps. The reviewer concluded that the long-term goal of achieving the materials with properties will be enabled by both the near-term investigation as well as the future tools in the mid-term efforts.

Reviewer 3:
The reviewer replied yes to this question.

Reviewer 4:
The reviewer replied yes to this question.

Reviewer 5:
The reviewer noted that the idea is to speed up the long-term research timeline from greater than 40 years to about 5 years, and as a result, the long-term research becomes near and mid-term.

Reviewer 6:
The reviewer stated that there appears to be, adding that the overarching theme of trying to move innovations to market faster through computational methods is a good way to achieve the desired result for materials. However, the reviewer cautioned, with respect to the aftertreatment projects, more funding is necessary to investigate the wide range of technologies needed to support advanced engine development.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer said yes, these are very clearly identified

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The reviewer answered yes, elaborating that speeding up long-term research is very challenging and requires intense collaborations between industry partners including original equipment manufacturers (OEMs) and suppliers, national laboratories, and academia. The reviewer added that most of the challenges are simply in communication between partners and access by the partners to the right analytical tools, and characterized DOE as well-positioned to facilitate these interactions.

Reviewer 4:
The reviewer described as sufficient the identification of important issues and challenges with accompanyin metrics to identify progress in resolving these, adding that the goals to reduce weight, increase power density, and engine metrics are admirable goals that must be solved in parallel with material improvements. The reviewer concluded the tools of using computational materials and national laboratories equipment to measure results on the scale that they are predicted are viable for solving near- and mid-term challenges.

Reviewer 5:
The reviewer replied yes, both in the area of lightweight materials and engine efficiency/aftertreatment. Howeve , from the data provided, the reviewer suggested that the program more generously fund projects under the materials umbrella, characterizing the breadth and scope of potential projects that could impact advancement in this area as not being at an acceptable level. The reviewer warned that the trend points to even less funding going forward and urged that this must be reversed to effectively support the activities of the major vehicle OEMs to meet efficiency targets for emissions and fuel economy. The reviewer remarked that given the size of the fleets that use internal combustion engines, even small advancements will have a significant impact on the nation s energy independence.

Reviewer 6:
The reviewer said yes, the workshop data projecting 2050 was presented and was a great overview. However, the reviewer noted that the data were from 2011 and said it would be great to see this renewed and see where we are in 2016. The reviewer also said it would be nice to see what else is available to do but did not make the cut because of the available budget. The reviewer commented that the challenges around holes in the models as they are combined is very important, and it is disappointing that this work was not funded to fill those holes

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer answered yes, noting that plans were clearly laid out and clearly-leveled targets stated.

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The reviewer characterized plans identified for addressing issues and challenges as sufficient and remarked tha the portfolio of projects reviewed in this program look comprehensive in the mechanical property requirements for future applications. The reviewer referenced the question and answer session, and added that tools feedback in the form of a meeting at The Minerals, Metals & Materials Society (TMS) 2017 to discuss gaps in integrated computational materials engineering (ICME) is helpful. Further structuring of these programs with specific deliverables toward these ICME gaps would be helpful as well.

Reviewer 4:
The reviewer replied yes, observing that the incorporation of very fast computing can directly speed up development. The reviewer further remarked that solicitations containing multiple partner-type requirements, including national laboratories with fast computing and sophisticated analytical tools, also help speed up materials development.

Reviewer 5:
The reviewer said yes, the talk covered issues with the trend of increasing peak cylinder pressures and increased engine out exhaust temperatures, and it also identified the lowering of catalyst inlet temperatures due to turbocharging and waste heat recovery. However, the reviewer added, that the presenters do not intend to fix the modeling issues they identified, and that is a major missed opportunit . The reviewer realized this is due to funding, but would be remiss if it was not identified in this revie .

Reviewer 6:
The reviewer answered not with respect to funding, and that this must be addressed.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer answered yes, adding it was also benchmarked against the time to market using non-computational methods to speed the movement of technology to market.

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The reviewer replied yes to this question.

Reviewer 4:
The reviewer said yes, remarking that the program continues to create wins with decreasing resources and then commenting that this is either a strong testament to the program manager’s capability to identify key technologies for impact, or to the fact that the field is so wrought with opportunity that it becomes a challenge to select a low impact project.

Reviewer 5:
The reviewer stated that including the chart looking at the technology implementation timeline was a useful metric to demonstrate the accomplishments of this program against the stated goals and also noted that the stated goals for the projects for achieving materials properties were accomplished. The reviewer remarked that a final technology product would be nice to highlight although difficult by the proprietary nature of working directly with an OEM or first tier suppliers

Reviewer 6:
The reviewer indicated that the overview did not include much in terms of progress details, observing that a lot of slides had the same words as last year. The reviewer pointed out that there was a crankshaft project noted as an example of faster progress than normal materials development and another item noted was access gained to the Titan supercomputing system at Oak Ridge National Laboratory (ORNL) for greatly increased computational speed for metal alloy modeling. The reviewer commented that the program is divesting itself of hybrid electric vehicle (HEV) materials in favor of the SuperTruck II project.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer praised the work that is being done as spot on with the intent and well aligned with the scope. The level of work in this area is well beyond any other presentations this reviewer attended at the Annual Merit Review. The reviewer added that it is very telling that so much of the U.S. Council for Automotive Research (USCAR) identified needs were materials issues

Reviewer 2:
The reviewer replied yes to this question.

Reviewer 3:
The review replied yes to this question.

Reviewer 4:
The reviewer stated that addressing the broad problems and barriers in the VTO is sufficient, in particula , the targets of high efficiency internal combustion engines and reduction of emissions through high performance materials is applicable. The reviewer added the parallel activities of properties and components is essential to the success of the VTO program.

Reviewer 5:
The reviewer remarked that the goal is higher engine efficiency and the projects included in this area are enablers for meeting that overall goal.

Reviewer 6:
The reviewer responded not adequately, characterizing the funding as a major roadblock with respect to the breadth of technologies that must be addressed.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO’s needs?

Reviewer 1:
The reviewer declared absolutely, characterizing it as an extremely efficiently managed program, well aligned with scope, and in step with the industry needs to maintain the competitive position of U.S. companies.

Reviewer 2:
The reviewer replied yes, the interaction of the program managers through yearly face to face meetings and multiple program updates throughout the year appears to be an effective means to keep projects focused and adaptive to changing project needs.

Reviewer 3:
The reviewer stated that the program appears to be well-managed, adding that this is good because on the surface it appears to be a very disparate set of technology areas. The reviewer remarked, however, the program manager appears to have both managerial skills and deep technical understanding that can help bring everything together.

Reviewer 4:
The reviewer replied yes to this question.

Reviewer 5:
The reviewer replied yes to this question.

Reviewer 6:
The reviewer characterized the focus of this program on materials properties and use of OEMs to develop materials and create applications as sufficient to address VTO's needs. The reviewer cautioned that whether this approach is effective depends on the extent to which the OEM partners and principals implement and publish results.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer characterized as a key strength the linkage of materials properties back to combustion modeling through optimizing thermal efficiency without materials constraints and then deducing what needs to be changed in materials technology to support this.

Reviewer 2:
This reviewer liked the program involving ICME and Materials for Hybrid and Electric Drive Systems. The former would significantly reduce the materials R&D time and the latter is very important for vehicles using renewable energy.

Reviewer 3:
The reviewer remarked that the computational approaches to advancing innovative materials appears to be working well and appears funded adequately, but that the engine efficiency and aftertreatment programs must be funded at a higher level to improve the ability to address all the needed areas of research.

Reviewer 4:
The reviewer described the key strengths of the projects in this program areas as including the following: Using a computational materials approach is a strength to this program to deliver a gap assessment as well as identify collaborative programs for further tools development; and many of the programs have OEM leads (e.g., Ford, GM, and Caterpillar) that have the benefit of both knowing materials requirements and using materials to design the latest components in propulsion materials. A key weakness observed by the reviewer is the reduction of funding year over year in a critical tool development environment.

Reviewer 5:
The reviewer noted for a few areas, budget seems to have been cut, which might impact continuity and incremental technological improvements in those areas.

Reviewer 6:
The reviewer stated one potential problem is that improving engine materials to withstand higher temperatures and allow for higher exhaust gas temperatures could jeopardize progress made in low-temperature catalysts. The reviewer elaborated that typically, there is a tradeoff to be made in catalyst activity at low temperatures and the high-temperature stability. The reviewer noted that the current catalyst technologies for stoichiometric operation can withstand 1,000° Celsius (C), but future materials might be only able to withstand 900°C or even 800°C peak temperatures. Thus, it is important to pay attention to the system impacts of changing components.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:
This reviewer strongly agreed that the projects comprising part of the materials portfolio represent novel and/or innovative technologies and approaches to help overcome the barriers and challenges that the industry is facing in a number of powertrain areas.

Reviewer 2:
The reviewer declared that exploiting the physical limits of the materials will enable new concepts in component design that incorporate the very best design approaches and will yield benefits beyond the immediate program

success. The reviewer also applauded the use of national laboratory equipment in new ways to validate computational materials approaches at the modeling length scale.

Reviewer 3:
This reviewer affirmed seeing many capable, good reputable OEMs, institutes, and universities involved in appropriate areas in which they have expertise.

Reviewer 4:
The reviewer replied yes, for example, the reverse use of combustion modeling is great.

Reviewer 5:
The reviewer replied yes to this question.

Reviewer 6:
The reviewer remarked that this was an overview and there were not enough details given on the projects to judge novelty. The reviewer also noted that no intellectual property (IP) was mentioned.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer remarked that from the presentation, it appears that the lightweight materials portion of the portfolio is well engaged. Speaking directly for the propulsion materials projects, the reviewer described all the projects as supported with the necessary partners to help ensure successful outcomes.

Reviewer 2:
The reviewer characterized the program has having engaged appropriate partners from OEMs, national laboratories, and academic institutions and suggested that further partnerships with computational materials companies will be useful in the future, adding that some of this engagement is dependent on the relationship of the OEM to the computational materials companies.

Reviewer 3:
The reviewer said yes, the major concerns in the U.S. were clearly engaged.

Reviewer 4:
The reviewer replied yes to this question.

Reviewer 5:
The reviewer replied yes to this question.

Reviewer 6:
The reviewer noted that the projects include numerous industrial OEMs, suppliers, and national laboratories as partners.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer affirmed yes, they were obviously well connected, and their views well represented

Reviewer 2:
The reviewer stated that meetings, experiments, and publications demonstrate effective collaboration between all partners.

Reviewer 3:
The reviewer answered yes, noting multiple project meetings with the interested parties each year and at least one face-to-face meeting between DOE, national laboratories involved, and the other members.

Reviewer 4:
The reviewer replied yes to this question.

Reviewer 5:
The reviewer replied yes to this question.

Reviewer 6:
The reviewer stated that it appears that the program area is collaborating but cautioned how effective it is will be shown in a few years when approaching commercialization opportunities for the materials developed in the program.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
Not as far as this reviewer is aware.

Reviewer 2:
The reviewer stated that, in general, there is good coverage with just one issue around the needed sensing technology which the reviewer thinks will come along with low-temperature operations very soon.

Reviewer 3:
The reviewer commented that adding low-temperature aftertreatment closes a previously existing gap, but that engine changes should be treated as part of the system, along with aftertreatment changes.

Reviewer 4:
The reviewer noted that gaps in the computational materials area have been discussed and will be reviewed with the broader community during a session of TMS 2017. This was discussed in the question and answer after the presentation.

Reviewer 5:
The reviewer asserted that resources are a gap in the portfolio. This person further explained that this is a major area for opportunity and noted that the resources are dwindling.

Reviewer 6:
The reviewer specified one gap that has eme ged, apparently as a result of reduced funding, is the area of low-temperature aftertreatment research projects. The reviewer pointed out that this was an area of innovation that was strongly stressed by the automotive OEMs through USCAR and the associated workshops and technology roadmaps. The reviewer also remarked that the current level of funding does not appear to be able to support this activity at the level required to help the OEMs find new technologies to meet future emissions challenges

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer replied no to this question.

Reviewer 2:
The reviewer replied not really to this question.

Reviewer 3:
The reviewer referenced prior comments to question 12 and stated low-temperature aftertreatment.

Reviewer 4:
The reviewer answered clearly so, but added that given the program’s resource constraints, it is doing amazing things.

Reviewer 5:
The reviewer said that component demonstration of advanced materials is pending but identified this as a difficul task, and that this would be a good area of focus, adding that nondestructive testing and examination of these new materials is missing in the approaches discussed.

Reviewer 6:

The reviewer remarked it needs to be acknowledged that improving high-temperature stability of engine materials could result in a lack of low-temperature aftertreatment materials that can withstand the potential higher peak exhaust temperatures. The reviewer suggested that this tradeoff should be emphasized more.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer replied no, the program is very comprehensive.

Reviewer 2:

The reviewer remarked that given the current budget, it would be difficult to include additional areas that would benefit from additional R&D resources

Reviewer 3:

This reviewer does not see how this program area can take on anything else given the limited budget.

Reviewer 4:

The reviewer replied yes, and added they are too numerous to list. The reviewer declared this is an amazing area of opportunity and the presentation did a great job of relating intent and scope.

Reviewer 5:

The reviewer noted sensing technology and materials to prevent heat loss from the engine skin/piping system.

Reviewer 6:

The reviewer offered that broader demonstrations of computational materials tools validated with research from this program area would follow well from the component demonstration mentioned above. The reviewer added that quality assurance and testing limits would be a helpful area to include in the future for these advanced materials.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer remarked that the program is going well and making progress continuously. This reviewer does not have any new ways to recommend.

Reviewer 2:

The reviewer commented that the current approach seems to be good at this moment.

Reviewer 3:

The reviewer replied none at this time.

Reviewer 4:

The reviewer stated that this is an underfunded area that shows a lot of opportunity.

Reviewer 5:

The reviewer remarked that for barriers to be addressed in an effective manner, adequate funding of joint DOE and OEM projects must be in place and that powertrain technologies based on combustion engines will be the primary mode of propulsion in the near- to medium-term as least. The reviewer concluded that not supporting activities that support these powertrains, where incremental improvements can have a large effect on fleet miles per gallon (MPG) and emissions, in preference to battery-based alternatives, would not be the best course of action.

Reviewer 6:

The reviewer warned that with half the funding going to SuperTruck II, and a lack of real information about what that will include because it is in the competitive phase, it is hard to offer up new approaches.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer had no specific suggestions and instead said to keep the current good working relationships with involved partners.

Reviewer 2:

The reviewer replied no to this question.

Reviewer 3:

The reviewer said none at this time.

Reviewer 4:

The reviewer recommended a reverse to the trend of funding cuts.

Reviewer 5:

The reviewer said more budget and claimed that the use of half the budget on SuperTruck II will jeopardize opportunities to fund other projects in the future. The reviewer suggested that spinning off the HEV component would help somewhat.

Reviewer 6:

The reviewer exclaimed increase resources, stating that this work is pivotal both to have the United States maintain the lead in transportation technology as well as in increasing efficiency and thus lowering ene gy usage rate. The reviewer commented that U.S. companies routinely compete against foreign concerns that are not under capitalist profitability expectations, and that the only way to maintain or grow U.S. market share is via technology improvements. The reviewer explained that if the future is not in unique materials, then we are building the future engines today, and we are defeated.

The reviewer remarked that the lead time for materials research puts it into a space where companies cannot afford to invest in it due to the distance in economic return. This person added that stakeholders do not have the patience to wait 15 to 20 years before a return on investment is seen. The reviewer concluded that work in this program effectively decreases that horizon time to a point where it is palatable and allows U.S. companies to maintain technology leadership.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses *(on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 7-1 – Project Feedback

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Novel Manufacturing Technologies for High-Power Induction and Permanent Magnet Electric Motors	Grant, Glenn (PNNL)	7-15	3.45	3.45	3.45	3.10	3.41
Materials Issues Associated with EGR Systems	Lance, Michael (ORNL)	7-22	3.38	3.13	3.50	3.38	3.27
High-Temperature Materials for High-Efficiency Engines	Muralidharan, Govindarajan (ORNL)	7-26	3.17	3.17	3.00	3.00	3.13
Enabling Materials for High-Temperature Power Electronics	Wereszczak, Andrew (ORNL)	7-28	3.33	3.33	3.33	3.17	3.31
Biofuel Impacts on Aftertreatment Devices	Lance, Michael (ORNL)	7-31	3.33	3.25	3.08	3.17	3.24
Applied Computational Methods for New Propulsion Materials	Finney, Charles (ORNL)	7-34	3.39	3.50	3.39	3.33	3.44

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines	Huff, Rich (Caterpillar)	7-39	3.39	3.50	3.39	3.33	3.44
Integrated Computational Materials Engineering Guided Development of Advanced Cast Aluminum Alloys For Automotive Engine Applications	Li, Mei (Ford)	7-44	3.46	3.33	3.42	3.33	3.38
Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines	Walker, Mike (General Motors)	7-51	3.13	2.88	3.31	3.00	3.01
High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines	Shyam, Amit (ORNL)	7-57	3.40	3.50	3.50	3.40	3.46
Development of High-Performance Cast Crankshafts	Huff, Rich (Caterpillar)	7-61	3.38	3.13	3.50	3.38	3.27
Innovative SCR Materials and Systems for Low-Temperature Aftertreatment	Wang, Yong (PNNL)	7-64	3.25	3.50	3.17	3.17	3.35

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Next Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines	Lambert, Christine (Ford)	7-68	3.50	3.50	3.30	3.30	3.45
Sustained Low-Temperature NOx Reduction (SLTNR)	Zha, Yuhui (Cummins)	7-73	3.50	3.63	3.50	3.38	3.55
Overall Average			3.36	3.33	3.37	3.22	3.33

Novel Manufacturing Technologies for High-Power Induction and Permanent Magnet Electric Motors: Glenn Grant (Pacific Northwest National Laboratory) - pm004

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of 10 reviewers evaluated this project

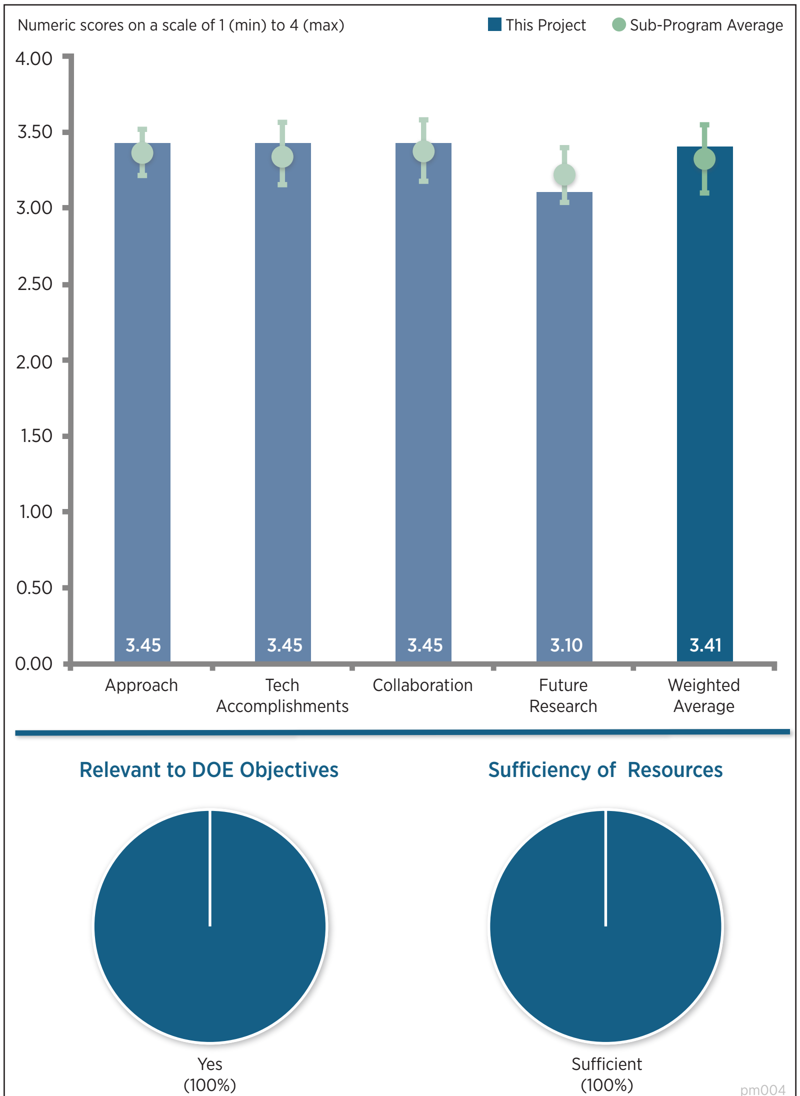

Figure 7-1 – Novel Manufacturing Technologies for High-Power Induction and Permanent Magnet Electric Motors: Glenn Grant (Pacific Northwest National Laboratory) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that this project is near completion with no new funding for fiscal year (FY) 2016 and noted that Dr. Grant provided an excellent overview of the project and its accomplishments. In addition, the reviewer highlighted that the approach to developing a solid state weld procedure that will ultimately lead to lower cost manufacturing of copper (Cu) rotors was well stated and included systematically developing solutions to controlling temperature, experimental determination of weld protocols, tool design and working with the industrial partner to characterize welds and iteratively improve the overall process.

Reviewer 2:

The reviewer indicated the approach is addressing improvements to induction motors that have the opportunity for lower cost and removal of critical materials (rare earths), which is very important and that the project addresses a key efficiency loss area for induction motors (joining of rotor bars to end caps). In addition, the reviewer acknowledged the approach applies a previously developed DOE VTO materials technology process (friction stir welding [FSW]) for a new problem, which is an excellent use of DOE funds to extend previous success to a new area. This project has a good balance of technology exploration, scientific research, and practical manufacturing considerations. The process for the work is appropriate for the technology readiness levels (TRL) being addressed.

Reviewer 3:

The reviewer concluded the project has excellent manufacturing process development with FSW and an automotive OEM.

Reviewer 4:
The reviewer stated the project has an excellent approach and that the technique can be applied to other applications.

Reviewer 5:
The reviewer described looking at things like the buy to drive ratio and other production concerns as great work. The project team has a clear understanding of what is necessary for commercial success of the process.

Reviewer 6:
The reviewer explained the project is specifically focused on improving manufacturing techniques associated with producing higher performance and lower cost motors. In addition, the focus is on moving from aluminum (Al) to Cu to take advantage of greater conductivity leading to greater energy density. The reviewer noted the project is being performed under a cooperative research and development agreement (CRADA) and at the end of the project the process technology will be transferred to the industrial partner.

Reviewer 7:
The reviewer reported the approach looks satisfactory and that welds proved good and viable manufacturing route.

Reviewer 8:
The reviewer said the project is a TRL 4 to 7 project and not traditional research. In addition, there is less fundamentals characterization with more focus on manufacturing process development. The focus is on improving performance and lowering the cost through better use of materials and simpler manufacturing method of Cu-based induction motors as an alternative to rare-earth based interior permanent magnet motors. The reviewer stated that while there is OEM support for this project by General Motors (GM), besides Tesla Motors using them in their vehicles, there does not seem to be significant interest from other OEMs. Most OEMs have taken the pathway to minimize or completely eliminate dysprosium (Dy), due to relatively very high cost, along with reducing other rare-earth materials neodymium (Nd). In addition, the reviewer explained there have been several successes in reducing rare-earth magnet content significantly (and therefore cost and potential future volatility associated with rare-earth prices) in integrated permanent magnet (IPM) motors without impacting the performance.

Reviewer 9:
The reviewer explained the project is designed to move the technology from research (TRL 4) to nearer to production-ready (TRL 6) to hand off to GM to commercialize. The reviewer agreed the approach seems to be well-designed for solving the technical issues of developing the friction-stir welding process for Cu. The reviewer said that the justification for this as an alternative over would-be expensive Cu was stated, so the approach seems valid. The stated barriers are decreased motor cost, decreased weight, increased durability, and increased efficienc . The application baseline is an induction motor, so a motor produced by the method developed in the project would increase efficiency and decrease weight (two of the barriers). The reviewer cautioned improved durability is only stated on a summary slide with no technical backup. The total motor cost impact is not stated. The project objective was to develop a low-cost FSW method, but the cost relative to the baseline was not stated. In addition, the overall motor cost (conventional versus the developed motor) was not stated, so unable to rate progress at the motor level.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer pointed out that the defect free rotor welds are very impressive. It shows a lot of work went into this accomplishment. The complex control system algorithm necessary to improve temperature control is also impressive work. This controls approach shows very good control of temperature in the weld, which is critical for avoiding distortion of the welded parts. The reviewer agreed that thorough examination of the weld end problem gives a simple and manufacturing-appropriate solution and indicated that runoff tabs are an appropriate solution. The reviewer commented that it is very important that the rotors have passed all the rigorous OEM tests for durability and performance, as this demonstrates both the quality of this research product and the OEM's interest in the technology.

Reviewer 2:

The reviewer applauded that the project is completing on budget and is extending the period of performance without increasing cost. The reviewer reported that the technology is ready for commercial application. In addition, the control of torque plus temperature has improved quality of weld. This reviewer noted that the exit hole solution is a runoff tab. The reviewer stated lower scrap metal is the easiest approach to complete weld.

Reviewer 3:

The reviewer explained the project is nearly complete and with the exception of the forthcoming technology transfer to the industrial partner and uncertainty associated with production costs, the project achieved its goals and fully addressed the barriers. In addition, the reviewer reported that Cu rotors have passed all electrical and performance tests at GM. The reviewer indicated a CRADA is the mechanism for transferring technology to industry.

Reviewer 4:

The reviewer concluded the project appears to be close to providing a product, and the project team is now working closely with production engineers at this point. The reviewer agrees the project team appears to have learned a great deal about manufacturing issues and developed several solutions along the way. The project team also appears to have developed welding methods that provide defect-free units by developing temperature-controlled welding methods. In addition, the project team now has identified what the team believes to be the best approach for minimizing complexity and waste by using a runoff tab. The reviewer remarked overall progress on the project has been a bit slower than anticipated throughout the project, although progress has clearly been made. There was one milestone delayed from fourth quarter 2014 to 2016.

Reviewer 5:

The reviewer stated several technical accomplishments including temperature control algorithm effectively addressed the rising temperature issue related to rotor welds which is +/- 2°C temperature control. The amount of Cu removed has been minimized in exit holes of shorting bars in the rotor, successfully. The reviewer noted the project team completed destructive, balance, resistance and electrical continuity and homogeneity of welds tests. The reviewer suggested because this project is relevant to the DOE VTO Electric Drive Technologies (EDT) subprogram, progress should be coordinated with EDT and also be measured against its targets (electric motor costs, specific powe , power density, and efficiency) to better gauge significance of the potential impact of thi project.

Reviewer 6:

The reviewer commented that feedback control on temperature of the welds is an innovative step forward for the FSW process.

Reviewer 7:

The reviewer observed that it was nice work changing the friction stir to constant torque to make the process more consistent. Controlling temperature is critical to more than this project and the reviewer mentioned the technology will find other applications

Reviewer 8:

The reviewer cautioned several slides and accomplishments were repeated in 2015 and 2016, so the presentation does not only show last year's progress. The temperature control effect on final weld is clear in the picture and data. It is unclear what accomplishments happened in FY 2015, which is the period under review. The results shown indicate that the runoff tab is a successful exit hole solution that appears to be the best option for GM to implement. Full rotor testing has been done by GM and had good results of same or similar resistance and induction performances compared to based cast rotors and spin and balance tests. The presentation was focused on the FSW process. The reviewer said that the project's performance for meeting DOE's overall motor cost, weight, durability, and efficiency at the motor level were not described. The project has been delayed some, but appears to be in the final stage where the process is being readied to transfer to GM. The Stationary Shoulder Tool development plan was shown in the 2015 and 2016 presentations. The reviewer was concerned that finding a workable solution appears to be an issue. Because the presenter briefly mentioned this and stated that the project team has a working solution, the reviewer opined that this implies it is an issue. The reviewer indicated it is unclear whether the issue is really solved, or if this approach was abandoned.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the collaboration shows a good distribution of responsibilities based on expertise between Pacific Northwest National Laboratory (PNNL) and GM. The project team has had close collaboration with GM, including final testing of completed rotors and use of this testing to improve the PNN FSW process. The reviewer stated the team's goal of passing the complete process to GM is excellent, as it will enable the OEM to begin using the process to manufacture electric motor components for themselves.

Reviewer 2:
The reviewer indicated the project team is very well connected with GM, their industrial partner. In addition, the reviewer stated that the testing GM has performed was important to provide commercial expectations.

Reviewer 3:
The reviewer acknowledged the project is closely coordinated with an ultimate user, GM (under a CRADA). At the end of this fiscal yea , the plan is to transition the project to GM, reported the reviewer.

Reviewer 4:
The reviewer stated there were very close collaborations and interactions with GM.

Reviewer 5:
The reviewer pointed out that GM, as the largest domestic OEM, is a very appropriate partner and has been engaged throughout the project.

Reviewer 6:
The reviewer stated that the project team is in continual iterative interaction (sharing parts, test data, and results) with GM, which is the sole commercial partner due to CRADA arrangement. The reviewer indicated that because this is a CRADA, no other collaborations were expected.

Reviewer 7:
The reviewer stated GM is heavily involved and is transitioning this process to commercial production.

Reviewer 8:
The reviewer mentioned the cost share and technical input provided by the industrial partner contributed substantially to the success of this project. Given that the results of this project were closer to the implementation phase (TRL 4 to TRL 6), the focus on process control, manufacturing technique and cooperation and feedback from the partner was instrumental.

Reviewer 9:
The reviewer said collaboration was explained during the presentation and GM seems interested in continuing to manufacture rotors like the one discussed in the future.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated the extent of the possibilities of this work is not nearly completed, and the funding is ending. The reviewer concluded this project deserves a second look as the commercialization opportunities are evident and close to a deployment stage.

Reviewer 2:
The reviewer stated the project is scheduled to end in September 2016. The Principle Investigator (PI) clearly identified several remaining challenges and barriers to be addressed through the end of F 2016, but appeared to feel these activities would be completed on time.

Reviewer 3:
The reviewer stated the project is ending this year.

Reviewer 4:
The reviewer said the goal is to transfer technology to GM and by the end of the project in FY 2016, four full size optimized, fully defect free and weld temperature controlled rotors will be delivered to GM for testing. The project is also aiming to develop and demonstrate shouldered tool assembly for further minimizing material wastage and part deformation by the end of the project at the end of FY 2016.

Reviewer 5:
The reviewer stated that the work is very appropriate and to wrap up this project will transfer the FSW process to GM. The reviewer suggested it would be good to transfer some future work to the EDT program in VTO which will continue the great progress and address broader and larger scale motor designs.

Reviewer 6:
The reviewer indicated the use of Cu with a higher conductivity is proposed to lighten the weight of the rotor assembly and questioned if this process is viable at lighter weight designs.

Reviewer 7:
The reviewer said the project is in its last phase and PNNL will have the fixturing problem and solution developed by the end of the project. The reviewer reported that transferring the process to GM is the last step and will be done next year.

Reviewer 8:
The reviewer indicated technology has been developed for FSW process and the project team is looking at other applications in the 60-80 kW motor range. The reviewer observed continued effort to determine GM’s interest regarding how to move forward, however, GM is interested. The reviewer noted no plan forward with other applications.

Reviewer 9:
The reviewer observed the project is near completion and the only task remaining in FY 2016 is completing the fixturing syste

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated the processing was fast enough to support a commercial application on a common opportunity that has many obvious applications in propulsion materials. The novel concept opens a lot of new doors for related opportunities as well, suggested the reviewer.

Reviewer 2:
The reviewer observed the project is focused on improving electric motor performance and cost for electric motors through improved manufacturing techniques. The reviewer suggested this is highly relevant for electrified vehicle applications. These motors are also used in non-electrified vehicle applications that are aimed at efficienc improvements, such as cylinder deactivation. The reviewer said by moving to Cu-based motors, there can be reductions in weight of 23% and size of 30%. The reviewer stated that this work is highly relevant to DOE and VTO overall objectives.

Reviewer 3:
The reviewer stated this activity enables more rapid and cost effective manufacturing of a key electric motor component.

Reviewer 4:

The reviewer indicated electric drive vehicles are one of the key technologies for petroleum reduction, which is the main DOE VTO goal. Current commercial electric drive vehicles are primarily depended on IPMs. IPMs use almost exclusively neodymium magnets with Dy used for protection from demagnetization at higher operating temperatures. Because Nd and Dy are heavy rare-earth magnets and are identified as critical materials by the DOE, improving induction motors, which is a competing technology to IPM, is a good alternative for protecting vehicle manufacturers from rare-earth magnet price volatility, which occurred in 2011 due to a significant spike in price due to limited supply. The reviewer said that improvements to induction motors that have been around for nearly 100 years have been very hard to come by.

Reviewer 5:

The reviewer stated this project addresses the material needs of the EDT team by developing lower cost and higher efficiency motors that will ultimately reduce petroleum use

Reviewer 6:

The reviewer mentioned there is a good opportunity to use a more efficient material which has difficulties to pou due to higher melting temperatures and that weight and power efficiency improvements are expected

Reviewer 7:

The reviewer stated induction motors are less expensive than permanent magnet motors because there are no expensive rare-earth metals, therefore, there is support for market adoption of plug-in electric vehicles. The reviewer indicated the specific motor involved in the project is a low-power mild-hybrid motor which the market appears to be moving to as the next step (e.g., 48 vehicle dynamic control mild-hybrids) for fuel economy improvements. The reviewer mentioned the project uses Cu shorting bars which replace Al bars. This provides higher power density because of Cu's higher conductivity. The result is a motor that is 23% lighter and 30% smaller than an Al-intensive machine. This is vital for electric vehicles (EVs) and for meeting DOE mass reduction goals. The reviewer explained it appears induction motors are the standard for the mild-hybrid application and indicated the presenter stated that the project is to develop a low-cost method to join the bars to the end caps using FSW. The reviewer said this is good for improving the power density. The reviewer commented the cost comparison between conventional manufacturing (die-cast) and this approach was not described and the presenter did not mention the cost impact of the developed approach (including the materials cost), especially when compared to current low-cost die casting for all-Al motors.

Reviewer 8:

The reviewer stated this project provides the low cost process to get the induction motor cost competitive and in production.

Reviewer 9:

The reviewer said the project contributes to improved process control and manufacturing techniques and greater efficiency is a key vehicle component

Reviewer 10:

The reviewer indicated the development of cost-efficient manufacturing technologies of motors is beneficial t lowering the price of EVs and HEVs.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated the project team has achieved their milestones within their budget constraints.

Reviewer 2:

The reviewer reported that work during FY 2016 was under a no-cost extension, and that the PI thinks the project is fine. The reviewer suggested after FY 2016, when the project will be transitioned to GM, there could be some future support through the EDT program.

Reviewer 3:
The reviewer said the resources allocated for the project are adequate to complete the proposed work. The reviewer indicated there was no FY 2016 funding as the project is continuing on carryover funds from FY 2015.

Reviewer 4:
The reviewer stated the project team is doing a very good job with the resources appropriated, and the resources have been sufficient to complete the work

Reviewer 5:
The reviewer reported this is the last year of their project and the tasks seem to focus on contributions at GM for implementation.

Reviewer 6:
The reviewer stated the project is developing a friction stir welded manufacturing process for joining Cu stator bars to Cu end caps. The project is developing the process to the stage it can be transferred to industry which at this time is only to GM because of the work being done under a CRADA. The reviewer commented that the overall motor design seems to have been done outside of this project and asked if it was done by GM. The reviewer indicated it is unclear whether developing this manufacturing process could have been done for less than $2.8 million total. It seems that the industry cost-share should have been higher to reduce DOE funding for this work because the CRADA was only with GM, who will be the only beneficiar . Resources were rated as sufficient because the reviewer may have missed some details.

Reviewer 7:
The reviewer noted the project is fully funded and is coming to a conclusion this year.

Reviewer 8:
The reviewer stated the money was well spent in this project.

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Materials Issues Associated with EGR Systems: Michael Lance (Oak Ridge National Laboratory) - pm009

Presenter

Michael Lance, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

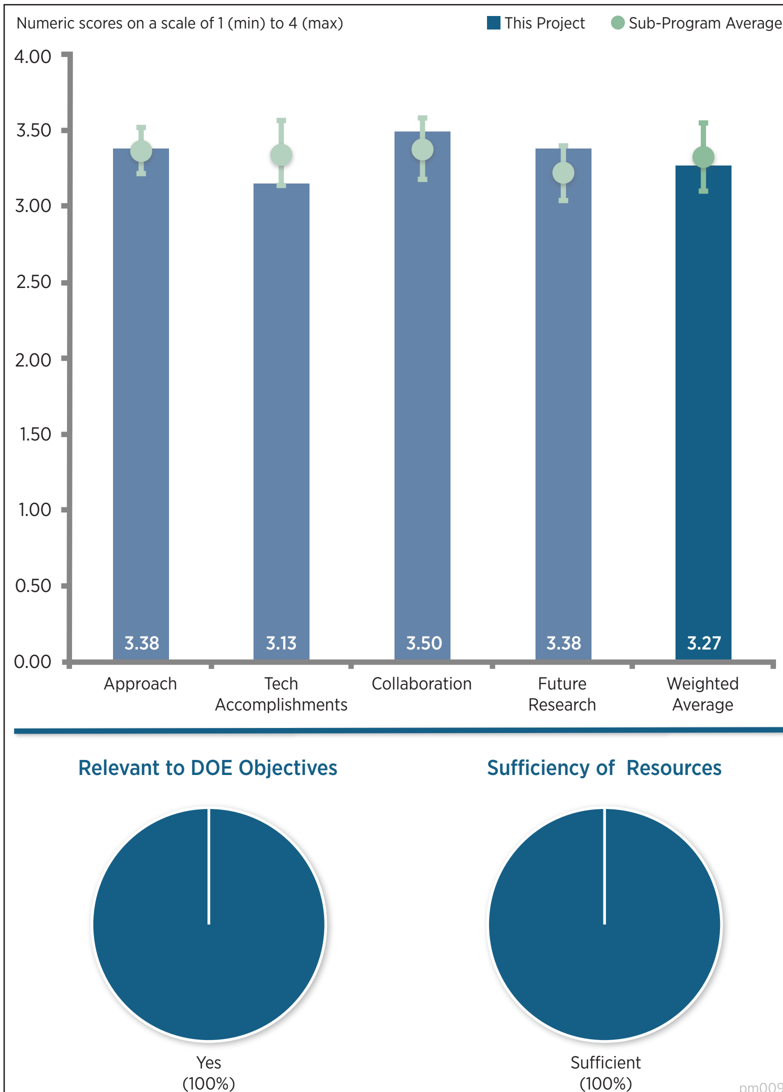

Figure 7-2 - Materials Issues Associated with EGR Systems: Michael Lance (Oak Ridge National Laboratory) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated the project appears to have a properly-focused and reasonably complete approach and is addressing exhaust gas recirculation (EGR) cooler fouling from a materials perspective. The reviewer indicated that to start the project, ORNL went to all the U.S. diesel engine manufacturers to find out what the biggest issue was facing EGR systems. The reviewer reported all of the engine manufacturers said EGR cooler fouling was the biggest issue. The reviewer mentioned the project team then obtained in-use EGR coolers from industrial partners and worked to address fouling through both active and passive (geometry/materials) control.

Reviewer 2:

The reviewer said the use of EGR for increased oxides of nitrogen (NO_x) emission performance and engine efficiency su fer from loss of thermal efficiency due to hydrocarbon (HC) fouling. The reviewer mentioned the developed techniques used in this work to characterize HC fouling mechanisms of EGR has been useful, as an initial step, to compare and contrast actual deposition with that predicted from models. The reviewer noted this provides a way to further validate predictions from computational fluid dynamics (CFD) models to capture the necessary components such as shear forces to predict the deposition process. The techniques used to determine the deposit thickness and distribution are very appropriate and utilize the resources available at the national laboratories, said the reviewer.

Reviewer 3:

The reviewer stated the project is aimed at getting a better understanding of EGR cooler fouling mechanisms to affect more efficient cooler designs for supporting the confluence of future more restrictive $_x$ limits and greater use of advanced combustion techniques like low-temperature combustion. In addition, the project is using a systematic approach involving initial characterization of deposit formation and aging, and investigating EGR cooler designs and geometries for mitigating deposit formation. The reviewer mentioned FY 2016’s five facto , three-level design methodology is a good example of this systematic approach to determine main influencers on deposit formation and mitigation. Also, two new techniques for measuring deposit thickness were developed as part of the research. The reviewer explained that the project team did look at new coatings and alloys early in the project to determine their impacts. The reviewer agreed the survey to elicit industry input on the research problem and industry participation is good.

Reviewer 4:

The reviewer stated the project team did a nice job tying the change being sought to an improved brake thermal efficienc .

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer explained the work showing the temperature variation in the cooler effecting the location of the deposit was stellar. The reviewer indicated this was a nice find and great work. The reviewer said that data also indicate that a good portion of the EGR cooler is not removing heat, indicating they can remove mass and not effect efficienc . The reviewer indicated the shear force hypothesis is important as well.

Reviewer 2:

The reviewer mentioned good progress has been made to characterize the actual deposit depth and how that varies with temperature, EGR geometries, and shear forces present. The reviewer explained that using this information to correlate with a CFD model will help predict the expected behavior under realistic conditions.

Reviewer 3:

The reviewer observed that the project found that heavily fouled coolers were not really impacted by geometry design, but low-hydrocarbon deposit coolers were. ORNL had John Deere foul coolers so they could look at the impact of geometry. The reviewer noted the result of this effort was that the project team found that the center is often significantly hotter than the outside of the cooler and that lower EGR inlet temperatures led to greater deposition, as did hydrocarbon content. The reviewer explained that the project team also developed a real-time method for generating three-dimensional (3D) images to see inside operating cooler and that actual deposit thickness measurements contradicted modeling results. The reviewer said the project team indicated that modeling did not adequately account for shear forces on the upstream side of the cooler fin and that the project team has started working with the Georgia Institute of Technology (GT) to improve the model.

Reviewer 4:

The reviewer indicated the total project timeframe seems like an inordinate amount of time to obtain significant results; however, the DOE Program Manager explained in the question and answer session that the project initially took some time to get traction while waiting for OEMs to provide information and support. The reviewer concluded that given the extended project timeframe, the continued industry participation in the project is critical to ensure the project stays relevant to industry research and needs in this area of NO_x control. The reviewer pointed out that a major accomplishments achieved this year included two new techniques for measuring deposit thickness and determination of two primary factors impacting deposit formation, which are EGR inlet temperature and HC concentration. The reviewer indicated the new optical profilometer technique deposit measurements indicated different results than the CFD modeling conducted earlier in the project in terms of deposit locations. The researcher believed that this was due to the interaction of exhaust gas shear forces and cooler geometry which is currently not incorporated in the CFD model. The reviewer concluded this offers an opportunity for model validation and updating, which will be the focus of next year’s research under the project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated the inclusion of HD engine and vehicle manufacturers along with ORNL and university assets will benefit this project. This will provide a platform to provide appropriately prepared samples and analysis, the reviewer said.

Reviewer 2:

The reviewer mentioned the project is collaborating with all U.S. diesel engine manufacturers, plus Modine and GT, and indicated it took some time to get all manufacturers on board, but that was seen as critical to the completeness of the project. The reviewer pointed out it was perhaps a bit surprising that there was unanimity in industry's response on the largest issue facing EGR systems, which was EGR cooler fouling. The reviewer noted that from the presentation it was somewhat unclear how engaged many of the industrial partners, specifically the manufacturers, are in the project. Of the manufacturers, John Deere and GM seem the most heavily involved, the reviewer reported.

Reviewer 3:

The reviewer stated the project team has maintained good collaborative efforts by involving an industry advisory team comprised of nine industry partners: Caterpillar, Cummins, Detroit Diesel, Ford, GM, John Deere, Navistar, PACCAR, and Volvo/Mack. The reviewer indicated the industry team has provided significant input and participation in the project. The reviewer mentioned that in order to address the CFD model inconsistencies identified through deposit measurement observations in the work, the project team has enlisted GM and G for collaboration on CFD model updates next year.

Reviewer 4:

The reviewer noted the project team has nine industrial collaborators, including parts and data.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated future research activities seem appropriate, leveraging off past work and recent findings on CFD model inconsistencies with deposit formation to first update the model to incorporate shear force influence and focus on cooler designs for deposit formation mitigation and removal. The reviewer observed future work will also review fouled coolers provided by industry to measure deposits and assessing varying geometries against the sinusoidal geometry already evaluated and indicated this work should provide additional information on optimal cooler designs for mitigating deposit formation.

Reviewer 2:

The reviewer observed the future work planned to address remaining questions and fill the knowledge gaps is appropriate.

Reviewer 3:

The reviewer emphasized creating the model with GM and GT will be a great asset and should be quickly deployed to the industry.

Reviewer 4:

The reviewer pointed out the presentation indicated future efforts to revise models and revisit additional EGR designs geometries. In particular, collaboration with GM and GT was highlighted that it intended to result in recommendations for improved EGR cooler design. The reviewer indicated the project will also revisit coolers donated by industry partners for use in the geometry analysis.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer stated this work is relevant and supports overall DOE objectives by addressing EGR cooler fouling and its deleterious impacts on NO_x emission control efficienc . The reviewer suggested the problem of EGR cooler fouling may be exacerbated by future advanced combustion approaches, such as low-temperature combustion and efficiency enabling technologies such as waste heat recover .

Reviewer 2:

The reviewer said the project, which is aimed at reducing NO_x emissions with no fuel economy penalty, clearly is in line with DOE/VTO objectives. The reviewer indicated current technology tends to have a 1% efficiency loss now. The reviewer concluded as advanced engine technologies expand, there will be more demanding EGR operating environments, including lower temperature combustion and greater waste heat recovery and both of these will be hindered by EGR cooler fouling.

Reviewer 3:

The reviewer reported technologies focused on increasing engine efficiency while lower N_x emissions is critical to achieving the required performance targets of HD lean engine applications.

Reviewer 4:

The reviewer noted if the cooler becomes more efficient, engine efficiency increases as data in the presentatio indicated showing a greater than 1% increase in thermal efficienc .

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said annual project funding has been fairly consistent for the last four years and indicated the project team estimates that about 3% progress had been accomplished in FY 2016, and estimates total project progress is now at 75%. The reviewer commented project completion is anticipated in FY 2018, leaving two years to complete 25% of the research work. The reviewer mentioned the research team is adding additional resources including GT and GM, for supporting the CFD modeling initiative next year.

Reviewer 2:

The reviewer commented there has been good progress and project seems to be on track.

Reviewer 3:

The reviewer indicated this project is appropriately funded and staffed.

Reviewer 4:

The reviewer said no indication was made that the funding is not sufficient

High-Temperature Materials for High-Efficiency Engines: Govindarajan Muralidharan (Oak Ridge National Laboratory) - pm053

Presenter

Govindarajan Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

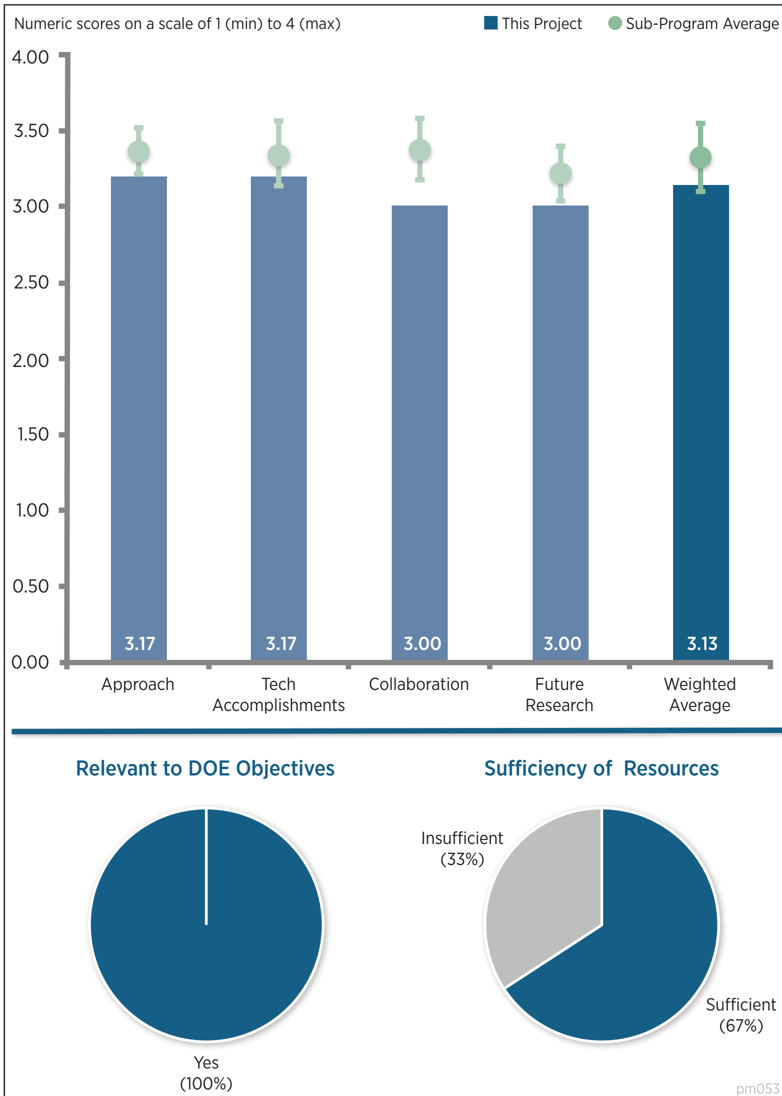

Figure 7-3 – High-Temperature Materials for High-Efficiency Engines: Govindarajan Muralidharan (Oak Ridge National Laboratory) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed this project seeks to develop new alloys that have combined improved strength, oxidation resistance and lifetime when operating at high temperature, up to 950°C. The approach combines computational thermodynamics including the ICME component of the research to support identification and characterization of higher strength alloys with experimental efforts to validate the modeling and to characterize the oxidation resistance of these alloys. The reviewer stated the project uses a combination of predictive materials science and trial and error.

Reviewer 2:

The reviewer was still confused at the progression of alloys studied in this work. The reviewer stated that Slide 8 in the presentation shows the third-generation alloy developed at ORNL but questions what the comparison on Slide 9 shows. The reviewer pointed out that the alloy designations are confusing.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the oxidation resistance is explained as better or worse many times during the presentation. The justification seems to have both characteristics present. The reviewer asked to please include a consistent metric for comparison of all results for determining the order of oxidation resistance.

Reviewer 2:

The reviewer noted that establishing a computational approach for predicting the yield strength of materials at temperature from average particle size distributions provided experimentally is a positive accomplishment though it requires additional investigation to quantify the disagreement between measurement and prediction of yield strengths. The reviewer stated establishing a weight percent minimum for nickel (Ni) plus cobalt to improve yield strength of new material versus commercial alloys and increasing Ni content to improve oxidation resistance is also notable. Overall progress on this project appears to be slow and behind schedule, reported the reviewer.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out the relationship between ORNL and Carpenter seems productive especially seeing the processing window determination.

Reviewer 2:
The reviewer said collaborations appear to be limited to use of Carpenter Technologies for material supply and some characterization and to Argonne National Laboratory (ANL) for additional characterization. The reviewer explained that based on the presentation material these relationships appear more like contractual agreements for support.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that there does not appear to be proposed work beyond the project scope and that the project is behind schedule and still has substantial work to complete prior to dissemination of final results

Reviewer 2:
The reviewer described proposed future research as sufficient for the present project

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer indicated the data for this material should have a positive influence on decisions to create a higher temperature and more efficient combustion cycle

Reviewer 2:
The reviewer noted the project's intent was to develop alloys capable of supporting more efficient engines (valves) at higher temperatures.

Reviewer 3:
The reviewer stated the development of high-temperature material is to increase the engine efficiency for fuel savings.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer warned it is not clear that there are sufficient remaining resources to complete the tasks outlined as future work for the remainder of 2016. Future work includes adding reactive elements, fabrication of down-selected alloy, testing, and completion of characterization and preparation of final report. This person said given that the project is already beyond its intended schedule, completion of all tasks with the remaining budget will be challenging. The September 2015 milestone was scaled back from down-selecting two alloys to one. The reviewer suggested that overall, it appears that the initial goals of the project were too ambitious for the level of funding provided or that there were unanticipated costs at some point.

Enabling Materials for High-Temperature Power Electronics: Andrew Wereszczak (Oak Ridge National Laboratory) - pm054

Presenter

Andrew Wereszczak, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

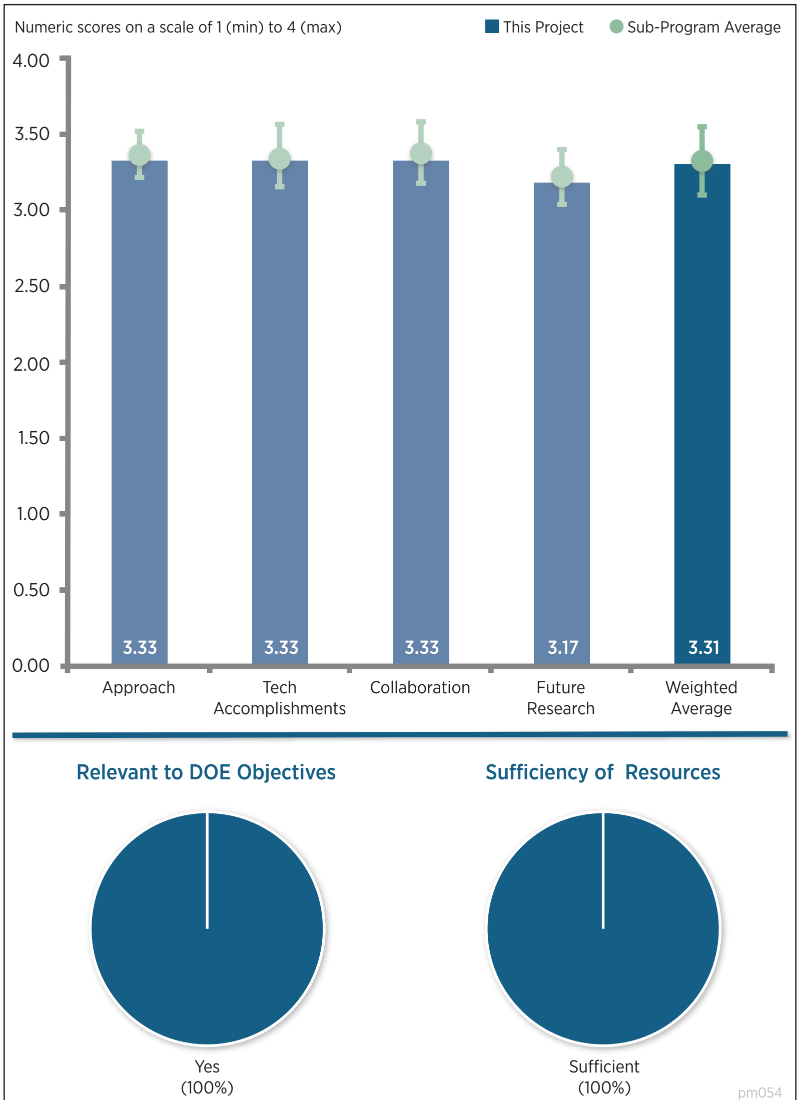

Figure 7-4 – Enabling Materials for High-Temperature Power Electronics: Andrew Wereszczak (Oak Ridge National Laboratory) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported a fairly thorough discussion of the issues, approach and results associated with high-temperature power electronics was provided. Substantial attention was given to the understanding of the potential manufacturing issues and the implementation challenges associated with sintered silver. In addition, a comprehensive research plan has been conceived, developed and executed. The reviewer commented for the funding provided, significant progress has been made but additional work is required to determine if this material is viable. The reviewer suggested that because this is the end of this project, the researchers should be encouraged to report results in a journal publication for reference in future efforts to continue development. The reviewer indicated the discussion on electric motors was minimal. Thermal conductivity was characterized through several methods and knowledge was gained on the anisotropy of the material said the reviewer. Because this task was apparently slated for only 20% effort, the results are useful but leave much work to be done. The reviewer commented that hopefully a publication either already exists or will follow that details proposed additional efforts.

Reviewer 2:

The reviewer said the team has effectively focused on two key material challenges in high-temperature power electronics; the interconnect material and high–temperature, high-thermal conductivity potting compounds. Other high-temperature material challenges were recognized but appropriately ranked at lower priorities. The reviewer indicated this effort will generate data that will be effectively integrated with other efforts, particularly National Renewable Energy Laboratory’s (NREL) efforts on measuring and modeling heat transfer.

Reviewer 3:

The reviewer explained in addition to the measurement of the anisotropic thermal conduction of this system, a model showing the limits or just system behavior is warranted.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the project team for making outstanding progress on developing sintered silver interconnects as an alternative interconnect material. The processing challenges of surface condition and plating requirements were well understood and tested. The important performance metric of failure stress was identified and measured, and specification limits were determined from those measurements. The reviewer said the various fracture and fatigue studies that were undertaken will provide valuable data for assessing the reliability and lifetime of systems manufactured with this technology. The reviewer pointed out the measurements of the thermally conductive potting compounds used in electric motor compounds seemed to be at an earlier stage of completion. The test matrix to be developed was not apparent but presumably will be in the paper that is in preparation the reviewer reported.

Reviewer 2:

The efforts to understand the challenges associated with the use of sintered silver in high-temperature power electronics cover material development, understanding material properties, manufacturing and mechanical testing, these tasks all provided substantially useful information leading to a greater understanding of the viability of sintered silver for this application. Several mechanisms associated with the potential loss of integrity of electronic structures were identified and characterized

Reviewer 3:

The reviewer questioned if a modeling approach was incorporated into this project such that the data and knowledge can be leveraged in the design of a new system.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said the team seems to have excellent interaction with ORNL and NREL in electric motor winding sample preparation and measurement. In addition, the team also seems to have had fruitful interaction with ORNL in assessing the fracture mechanics of the sintered silver interconnects.

Reviewer 2:

The reviewer affirmed good collaboration is seen for both sample creation and testing

Reviewer 3:

The reviewer indicated the teaming effort was solid.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated the remaining tasks focus on report writing, which seems appropriate given that the project is nearing the end of its period of performance.

Reviewer 2:

The reviewer reported that because the project is near completion, articles should be submitted for publication prior to end of the funding.

Reviewer 3:
The reviewer noted that sintered silver seemed to be favored, but the reasoning behind this choice was not clear. The reviewer asked whether this was CTE, strength driven, or something else.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer observed these projects indirectly supports the overall goal of petroleum displacement by enabling the development of more efficient power electronics and electric machines

Reviewer 2:
The reviewer commented reducing the cost and reliability of electric drive systems.

Reviewer 3:
The reviewer stated that if an argument for addressing the DOE objectives of petroleum displacement was made, it was missed. Improved performance in power electronics and electric motors will lead to greater efficiencies and longer life. The reviewer concluded that if that is sufficient for supporting DOE s objective, then a case can be made for this project supporting the objective.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer reported given the limited funding and the challenges of getting work done at national laboratories, the tasks accomplished within schedule and budget are notable.

Reviewer 2:
The reviewer stated the remaining resources seem sufficient to carry the project through its scheduled endpoint at the end of 2016.

Reviewer 3:
The reviewer said the project is ending shortly with additional tests and data.

Biofuel Impacts on Aftertreatment Devices: Michael Lance (Oak Ridge National Laboratory) - pm055

Presenter
Michael Lance, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

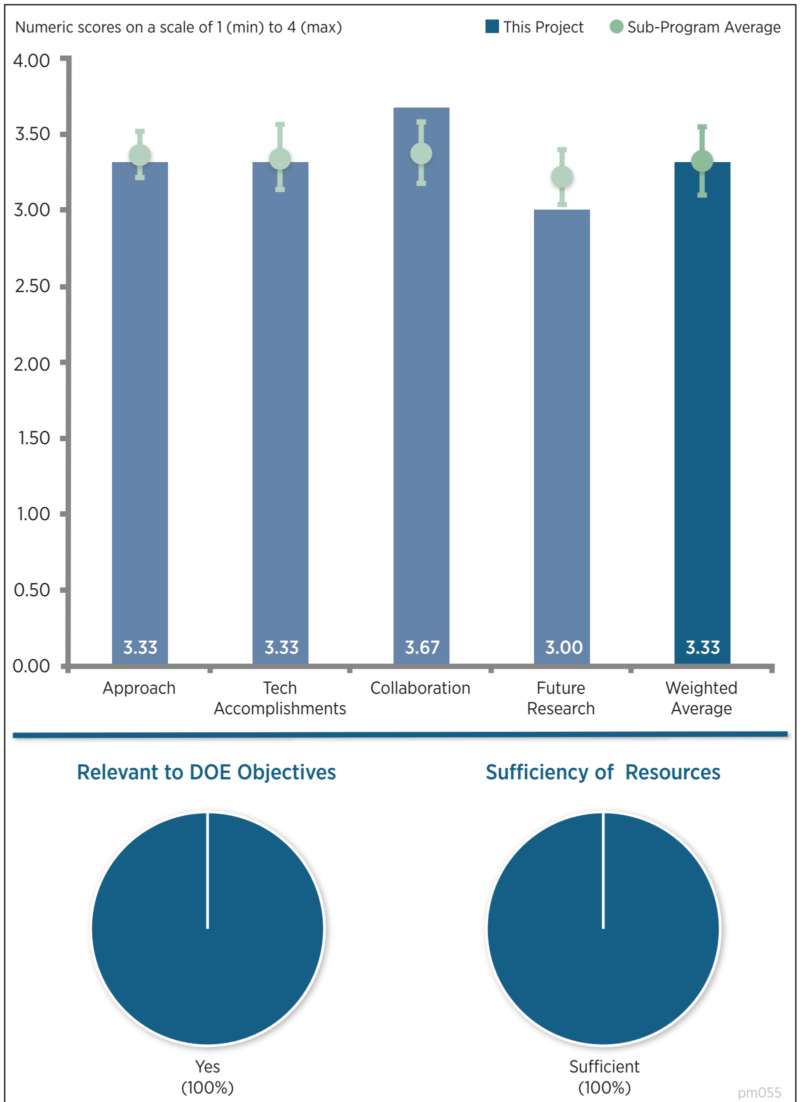

Figure 7-5 – Biofuel Impacts on Aftertreatment Devices: Michael Lance (Oak Ridge National Laboratory) - Propulsion Materials

Reviewer 1:
The reviewer observed nice applied work looking at a potential real world issue of biodiesel contaminant effects on exhaust gas catalyst system. The reviewer explained it is important to understand the underlying fundamentals of this issue, and noted that the barriers being addressed do not seem to match those in the propulsion materials area.

Reviewer 2:
The reviewer explained that the validation of the American Society of Testing and Materials (ASTM) standard is a great measurement tool for the effect of biofuel. The reviewer pointed out it is a nice approach to look at both running engines as well as forensic methods.

Reviewer 3:
The reviewer reported this work seeks to understand how components of biodiesel, remaining from the fuel synthesis process, effect the performance of the catalysts used in the aftertreatment systems used for diesel engines. Also included in the study is the effect of phosphorous, from engine oil, effects the performance of the aftertreatment catalysts. With respect to the contaminants in the biodiesel, those species studied here, sodium (Na) and potassium (K), result from first generation homogeneous fuel processing of biodiesel. Second-generation heterogeneous biofuel processes use catalysts that are composed of different elements. Therefore, the reviewer concluded one should expect the presence of Na and K to be much lower and less of a concern as a source of catalyst deactivation. In fact, the concentration of these species in the limited fuel survey may support this change in fuel source. The reviewer suggested an expanded fuel study, to determine if other species are present in higher concentrations, should be invested as a risk to catalyst performance. The actual testing of the effects of contaminants is reasonable reported the reviewer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer stated it was nice protocol to remove single elements and identify changes. In addition, the reviewer commented it was great work covering the lack of change in mechanical properties of the diesel particulate filter (DPF). The reviewer suggested tying the Na back to the ash content is very good and was nice to extrapolate the effect on real products.

Reviewer 2:
The reviewer noted nice progress towards detailed understanding biodiesel effects on each component in diesel exhaust system. However, the reviewer suggested because mostly steady state accelerated aging is only partially realistic, the stepwise approach to discover the fundamental issue of platinum (Pt) poisoning on direct oxidation catalyst (DOC) activity was interesting and novel.

Reviewer 3:
The reviewer stated this work used a thought-out method to assign the loss of catalyst functionality to a particular contaminant in the exhaust environment. The use of analytical tools and contaminant removal processes worked well and showed the effect of the contaminants on the activity of the various components of the exhaust aftertreatment. However, the reviewer suggested the evidence is less convincing for assigning Pt contamination as the cause of selective catalytic reduction (SCR) selectivity reduction. The inability to see the Pt in the SCR catalyst and where it might be concentrated, coupled with the placement of the SCR after the DPF, is not convincing evidence for this failure mechanism.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer explained the Manufacturer of Emission Controls Association, NREL and Engine Manufacturers Association participation increase the quality of this project and it is great to have them on board.

Reviewer 2:
The reviewer pointed out there is strong interactions with industrial partners.

Reviewer 3:
The reviewer said the partners involved in this work are appropriate.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed the generator work going forward is a good addition and is a very cost effective way to get the data and create samples. The reviewer concluded this may offer an opportunity to look at the variations associated with changing biodiesel feed stocks.

Reviewer 2:
The reviewer suggested the actual composition of biodiesel should be investigated first to assure the presence of Na and K are still present at levels that are significant to the aftertreatment system

Reviewer 3:
The reviewer suggested ORNL may want to look at the effect of exhaust condensate on DPF ash. The reviewer indicated it was mentioned that the presence of Na increases the total ash mass, but this is most likely mitigated by cold start conditions when liquid water is present in the exhaust system.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said understanding deactivation mechanisms related to contaminants in biodiesel fuel are of importance, because the use of biodiesel is increasing in the fuel marketplace along with green diesel.

Reviewer 2:

The reviewer reported if the degradation is not identified then a la ger system would be required for bio compatibility.

Reviewer 3:

The reviewer indicated understanding fuel and oil effects on aftertreatment devices can lead to more active emission control systems that enable more fuel efficient powertrains

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated this project is appropriately funded and staffed.

Reviewer 2:

The reviewer indicated the project team is on track and have a lot of data and analysis to support their conclusions.

Reviewer 3:

The reviewer said resources appeared adequate to cover the work.

Applied Computational Methods for New Propulsion Materials: Charles Finney (Oak Ridge National Laboratory) - pm057

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

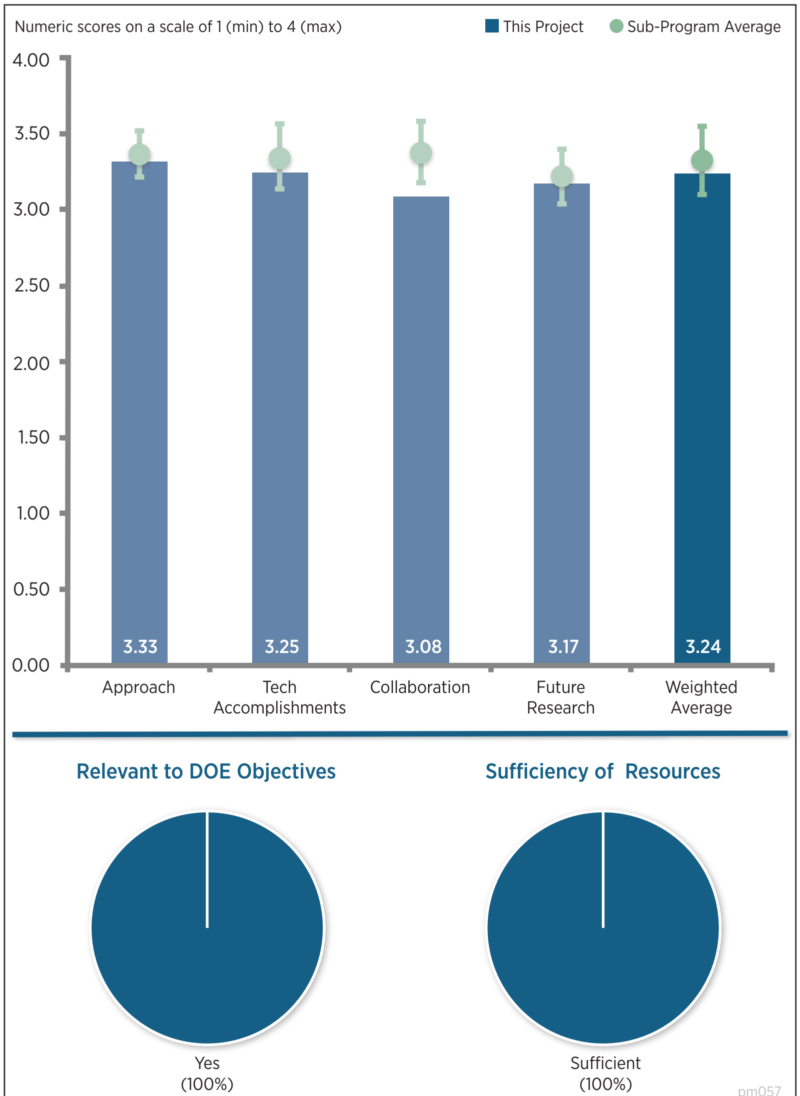

Figure 7-6 – Applied Computational Methods for New Propulsion Materials: Charles Finney (Oak Ridge National Laboratory) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised the technical approach that combines CFD, FEM and FE-SAFE to evaluate the material properties and said it is a systematic and reasonable method.

Reviewer 2:

The reviewer said this activity is successfully developing a combined CFD and finite element modeling (FEM) approach to predict where and how high-temperature thermal exposure affects engine components. There is good coupling with engine efficiency targets that require higher temperature materials to reach the efficiency levels needed going forward. The reviewer suggested understanding where high-temperature events are impacting the cylinder components and how the material reacts is very important to the survivability of the engine. Therefore, the reviewer concluded this work is highly encouraged.

Reviewer 3:

The reviewer acknowledged the project's approach appears rational and well-developed, based upon extensive experience in the technical area. Overall, the project is aimed at bringing together modeling and experimental validation to improve HD vehicle engine designs as well as to eventually extend successful techniques to light-duty (LD) engines. The reviewer noted that specificall , the project is focused upon using CFD to identify the overall operating environment within engines at higher peak cylinder pressures. Then, FEM is used to identify the impacts upon various engine components, thus estimating the performance needs for the materials used for these components. In addition, the reviewer stated this effort supports all SuperTruck activities. The reviewer mentioned that it should be noted that this review appears limited to only Task 4 of the five project tasks

Reviewer 4:

The reviewer explained that the review covered mostly Task 4, HD Engine Materials Requirement, like last year in 2015 but did also mention Task 5, Materials Characterization and Evolution, which was added from last year's review. The compacted graphite iron (CGI) characterization helped link Task 4 and 5 together. The reviewer pointed out that overall, the work is interesting and seems feasible in developing an improved understanding on the material property needs for both HD and LD engines.

The reviewer reported that because modeling is such a large component of this project, it would be appropriate to acknowledge the computational time and/or power needed for the CFD with conjugate heat transfer (CHT) coupled into the FEM. The reviewer indicated this would provide a better idea on the scalability of the CFD-FEM approach from the two material test cases to assessing a large number of candidate materials for new engine materials as part of the ICME effort.

Reviewer 5:

The reviewer pointed out that this approach seems like it should be common in the engine design community. The reviewer questioned if there are current cases that could be used as a baseline for the initial CHT simulations. In addition, the reviewer asked if these simulations will be validated at some point.

Reviewer 6:

The reviewer explained that the approach combines feeding relevant experimentally-derived material properties for compacted graphite iron (Fe) into the modeling stream that includes CFD that are integrated into finite element codes and conjugate heat transfer to explore various effects at higher temperature and pressures. The reviewer indicated that the results of these studies ultimately provide the stress and temperature parameters of engine components at peak cylinder pressures and drive fatigue models.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer agreed combining computation methods to better assign hot spots and how material will respond to temperature and pressure is a very appropriate. The work appears well thought out and focused. The predicted results are overall very consistent with the experiment. The reviewer suggested continued validation of the modeling is required to improve confidence, but current work appears to be driving material changes at the manufacturing level.

Reviewer 2:

The reviewer emphasized that during FY 2016 the project has nearly completed all milestones and focused on measuring properties for compacted graphite iron at higher engine temperatures. The only effort remaining for compacted graphite iron appears to be testing of short-term creep (which is currently underway). The reviewer indicated additional efforts were also completed in combustion modeling, and that CHT simulations are in progress.

Reviewer 3:

The reviewer said that the researcher provided a thorough discussion of the HD engine materials task within this project. The reviewer indicated this appears to be the only remaining task and is independent of tasks addressed at previous review meetings, which included piezoelectric, non-rare-earth and low-temperature catalyst materials tasks. The reviewer pointed out that possibly some of the methodology carried over from the other tasks. The reviewer commented that accomplishments in this task are on target and that the co-simulation of combustion and thermal properties is notable.

Reviewer 4:

The reviewer said the experimental part of the project is almost done and CFD simulation was started.

Reviewer 5:

The reviewer noted that Task 4 makes up a large component of this project and seems to be progressing well. The new conjugate heat transfer model implemented will provide better temperature distributions at the peak cylinder pressures of interest, in which the finite element method should simulate more accurate peak stresses of actual working engines. The reviewer stated that the results of the experimentally measured properties of compacted graphite iron are not only useful for this project, but also for the engine modeling community. The reviewer concluded that at this time, there is insufficient information on how the models will be evaluated for determining the guidance on the limits for targeted material properties, which will hopefully be present in the next review.

Reviewer 6:
The reviewer pointed out that variation is shown for the peak cylinder pressures, and questions how this will be compared to current practice to ensure that these predictions are in the right range and are showing the right behavior.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated there is good partnering with a leading HD engine manufacturer and that the project would also benefit from a LD engine partner because this work can carry over to that segment as well

Reviewer 2:
The reviewer noted that ORNL is collaborating with Cummins and Convergent Science. Cummins provided everything it had on the ISX engine to the project, and has outfitted test engine units to identify real engine operating environment requirements. Cummins indicated that it has learned a great deal already that will impact their future engine designs. The reviewer indicated that most of this information on collaboration was gained from the PI and the Cummins representative in the review room, rather than from the presentation. The reviewer said in future planned research the PI identified a desire to move toward adding LD engines, which will require an addition of a LD engine partner. The reviewer commented that the PI indicated the team is working on that, and have identified a common spark-ignition (SI) engine and partner for when those e forts occur.

Reviewer 3:
The reviewer explained that the contributions of the two partners listed were mentioned during the review and the collaboration effort briefly mentioned on the summary slide. The reviewer stated that while more discussion of the collaboration efforts would always be appreciated, it is acknowledged that partners may not want their roles to be described as pointed out during the presentation.

Reviewer 4:
The reviewer was not able to gain a clear picture of the collaborative relationships although it would appear likely that Convergent Science provided CFD support and Cummins would provide materials and operational input.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated the proposed future research is well planned out and on track to addressing the remaining subtasks within Task 4.

Reviewer 2:
The reviewer observed that models must be continuously updated to more accurately reflect the in-use experience both in the HD and LD markets.

Reviewer 3:
The reviewer stated future research is well planned for the remainder of FY 2016 and FY 2017 and that longer term opportunities for extension of methods to LD vehicles appear viable. The reviewer indicated a fully coupled CFD-FEM approach could be challenging.

Reviewer 4:
The reviewer acknowledged the PI clearly laid out the plan for future research, for FY 2016, FY 2017, and the future. The elements identified appear to make sense, and it is interesting to see that there has been thought given to how the techniques developed here would be applied to LD engines including the changes in concerns and challenges that sector would bring. The reviewer was concerned that the future portion of the list (beyond FY 2017) appears to show the full implementation of tools, which might have been hoped for before the project ended in FY 2017.

Reviewer 5:
The reviewer questioned if the baseline results will be published or how will this information be communicated to the broader audience.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer pointed out the project is aimed at identifying future engine materials needs to improve performance and thus efficienc , particularly through increased peak cylinder pressures and temperatures. Additional objectives are to identify materials with domestic supplies, reduce materials commercialization lead-times, and reduce engine weight. These are all extremely relevant to DOE and VTO objectives, the reviewer said.

Reviewer 2:
The reviewer remarked the project is well aligned with the DOE objectives of petroleum displacement by accelerating the discovery and development of new materials used in future engines for improved fuel efficienc .

Reviewer 3:
The reviewer indicated the project is to develop a faster and cheaper method of material development to enable advanced engine and powertrain systems for propulsion applications. The final goal is to increase vehicle efficienc for fuel saving.

Reviewer 4:
The reviewer noted the project directly addresses the needs for improvement in vehicle materials capabilities to enable operations at higher temperatures and pressures.

Reviewer 5:
The reviewer observed the establishment of material property targets for a baseline internal combustion engine is a good achievement. Further efficiency improvement may be more realistically set based on results such as this, the reviewer concluded.

Reviewer 6:
The reviewer indicated that improving survivability of materials under more demanding conditions due to increased engine efficiency is critical for manufacturers to ensure performance over engine life

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated this project is appropriately funded and staffed.

Reviewer 2:
The reviewer reported that no indication was made by the PI concerning the sufficiency of the funds, although the FY 2016 level appears to be a bit of a ramp-down from earlier years. The reviewer concluded this may simply represent the stage of the project, but it is unclear. Given overall funding tightness within PM in future years, it would be anticipated that any FY 2017 funding would likely be lower, suggested the reviewer.

Reviewer 3:
The reviewer said the resources appear to be sufficient to complete the remaining tasks

Reviewer 4:

The reviewer commented that to the extent it can be evaluated based on information provided in the presentation, the resources appear reasonable. It would be interesting to see where the project could go with additional funds dedicated towards it, the reviewer reported.

Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines: Rich Huff (Caterpillar) - pm059

Presenter
Rich Huff, Caterpillar

Reviewer Sample Size
A total of nine reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

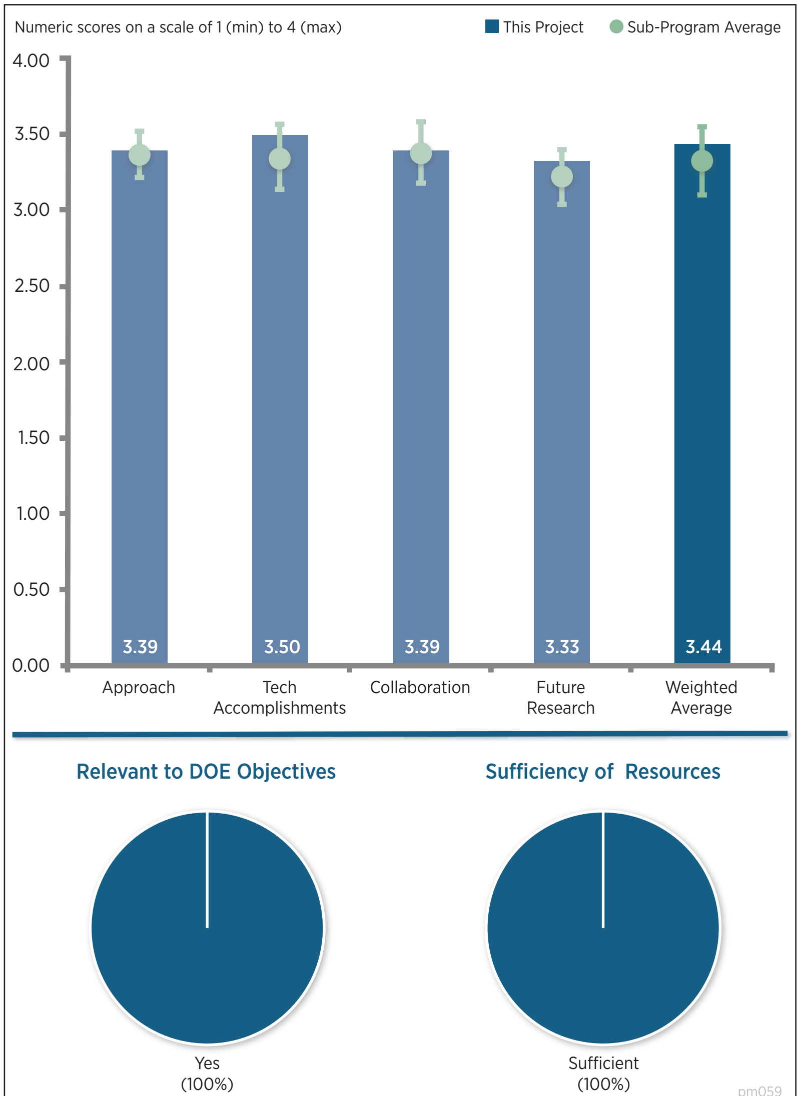

Figure 7-7 – Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines: Rich Huff (Caterpillar) - Propulsion Materials

Reviewer 1:
The reviewer commented that the approach is logical and the PI has described the steps quite well in the presentation. The process of starting with ICME and moving to prototype alloys and verification is appropriate. The reviewer said that the inclusion of cost modeling to understand how these alloys will impact the cost of components and systems is an important step for moving this research work into actual production. Especially notable is the use of advanced laboratory capabilities (e.g., the ANL advanced photon source [APS]) to understand the materials science behind these lightweight materials, the reviewer stated.

Reviewer 2:
The reviewer pointed out the project is an outstanding implementation of what now is becoming a standard approach to new materials development, which is computationally designing new material sets based on prior expert knowledge, developing prototype melts, characterizing microstructural and mechanical properties, developing test castings of final allo , and comparing results with modeling and predicted results.

Reviewer 3:
The reviewer indicated the thoroughness of the experimental approaches were impressive and seemed appropriate, but the materials system (cast iron) is extremely challenging due to barriers in modeling and predicting the structure of the Fe-graphite system. The reviewer said the approach considered refining primary austenite dendrites, refining eutectic cell size via inoculation, and improving the strength of the matrix by alloying or nano-precipitates, but the structure of these materials is extremely sensitive to cooling rates, which is a difficult boundary condition. The directional solidification studies to evaluate e fects of thermal gradients and cooling rates added some interesting scientific understanding, the reviewer noted

Reviewer 4:
The reviewer indicated the approach (interrupted solidification, visualization techniques, etc.) appears to be thorough, well-designed, and well-executed for understanding the formation mechanisms and composition the project is targeting to understand. The reviewer highlighted the following: the efficiency ta get is to achieve 214 Megapascal (MPa) endurance limit to enable higher cylinder pressure and temperature combustion regimes; the power density target is to achieve 25% increase in strength over A842 compacted graphite Fe; and various approaches for quantifying and improving strength were described. However, the reviewer noted the presentation lacked quantification of the endurance limit and tensile strength performance of the investigated alloys (including relative to the baseline). Also, there is no described effort yet regarding validating cost target (less than or equal to 110% of production A48 gray Fe cast units). This reviewer stated that cost models will be used this year to quantify. The reviewer mentioned it seems like cost analyses would have been included throughout project to ensure that the research path was cost-effective.

Reviewer 5:
The reviewer stated due to the need of higher strength materials that will survive the increased pressure and temperature requirements of more efficient engines, advanced modeling techniques are needed to predict performance. In addition, the pace of innovation in this area will benefit significantly from models that are capabl of directionally predicting how materials will respond to harsher environments. The reviewer pointed out that the work in this project directly addresses these needs through ICME. However, setting benchmark targets for cost of material must be well grounded in feedback from manufacturers. In addition, the reviewer suggested that heat rejection and conductivity must be an integral component of a model that predicts material behavior and suitability for an application.

Reviewer 6:
The reviewer said it is good to see some modeling work of the microstructure to study the physics behind it.

Reviewer 7:
The reviewer mentioned it is nice that the project is addressing the issue with modeling graphite influence in the Fe. The reviewer noted it is surprising that the project team is only looking at varying the nucleation akin to CGI instead of something with a higher return possibility.

Reviewer 8:
The reviewer commented the project team is using advanced experimental methods and characterizations to achieve the material properties needed, and ICME is being used to help with this.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer mentioned the project team has conducted extensive and systematic work to create and test a number of potential alloys, and conduct the required down-select based on microstructure and properties. In addition, the project team is doing a careful study of microstructures and their connection to material properties. The reviewer noted the interrupted solidification work appears to have been very successful, and provided considerable additional understanding of microstructure evaluation. The project team has made good use of the ANL APS for in situ solidification experiments, which provides a very interesting look at the evolution of the microstructure over time as the alloy solidifies. Thee reviewer concluded that this provides the team with extensive information on how to get the desired microstructures.

Reviewer 2:
The reviewer said the researchers have implemented their plans well and have made substantial progress this year, particularly with respect to casting materials, characterizing structural and mechanical properties, and multiple solidification studies

Reviewer 3:
The reviewer reported there has been good progress and a lot of work has been done.

Reviewer 4:

The reviewer stated the project team identified 30 high potential alloys, and developed strength models. The reviewer indicated solidification experiments with APS at ANL illustrated the issues of graphite formation, moving toward non-graphite (white) options.

Reviewer 5:

The reviewer reported good progress has been made identifying potential materials and characterizing those materials appropriately. The reviewer suggested more work must be performed to account for additional functional requirements of the materials such as heat rejection and the tradeoff involved in the casting process

Reviewer 6:

The reviewer reported that an impressive array of results (interrupted solidification, visualization techniques, etc.) was presented. The project team provided a detailed understanding of the alloy production process. This reviewer opined that these will be useful for Caterpillar and industry, possibly via DOE shared data, to develop commercialized metals. The reviewer noted that only FY 2015 accomplishments are shown, which makes it clear what was done in the period being reviewed. The reviewer indicated the milestone dates (completed, ongoing, and future) for many milestones changed between the 2015 and 2016 presentations, which created uncertainty as to whether or when the milestones were achieved and this is especially true for completed milestones.

Reviewer 7:

The reviewer said it was clear that improved properties have been achieved, but it was not clear in the presentation or the summary if the DOE materials properties targets are anticipated to be transferable to the cooling rates of actual cast components. The reviewer reported the DOE targets were 25% increase in strength over A842 CGI, and 214 MPa endurance limit at no more than 120% of cast of A48 gray Fe. The reviewer questioned at what temperature this occurred. Unfortunately, the presentation did not clearly identify the baseline strength of A842 CGI, so it was difficult to gauge progress, the reviewer observed. The reviewer pointed out the solidification, characterization and modeling work was impressive. The clear conclusion that satisfactory ICME tools are not available for fundamental modeling and design of cast irons is a valuable outcome, and can help shape both future reliance and investment in computational methods for cast irons.

Reviewer 8:

The reviewer noted the presentation did not clearly identify where the team is in relation to the targets with the down-selected alloys they are developing. The application of the solidification rate changes is important and they were addressed, they are keeping the option of post processing, such as heat treatment. The reviewer said the project has shown the complexity of grey Fe, and the need for increased modeling capability

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said there appeared to be excellent collaboration with other organizations, and the roles of Questek, University of Alabama at Birmingham (UAB), and ANL were all clearly described.

Reviewer 2:

The reviewer stated there is excellent balance of partners, academic and national laboratory capabilities which are integrated into the project.

Reviewer 3:

The reviewer reported the collaborative team appears well suited to achieve the project goals. Automotive OEMs should be involved as well to provide addressable needs for the LD market as well.

Reviewer 4:

The reviewer mentioned the project team is clearly working between several institutions as necessary.

Reviewer 5:

The reviewer noted the team has a good balance of industry, national laboratory, materials, and academic partners with the necessary capabilities to complete the work successfully.

Reviewer 6:
The reviewer said that there is a clear distribution of tasks among the collaborators that enables work to be performed in an efficient and timely manne .

Reviewer 7:
The reviewer mentioned the collaboration map is nice and clear.

Reviewer 8:
The reviewer explained that the project team is collaborating on the project with QuesTek Innovations (ICME), UAB (experimental testing), and ANL (APS facility for measurements and visualization). The reviewer mentioned the Northwestern University role was not clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the project team provided a clear explanation of the remaining barriers that demonstrates their understanding of the challenges that remain. The project team is working on component designs and scale up of casting processes, both of which will be very useful for eventual commercialization.

Reviewer 2:
The reviewer agrees with future activities.

Reviewer 3:
The reviewer commented that the future steps were clearly described and were in alignment with project goals.

Reviewer 4:
The reviewer commented that the plan for scale-up trials (1,000 lbs. and prototype parts using the developed ICME approach) are good steps to validate model and material performance. The reviewer pointed out that the budget for the project is 70% complete, and that Slide 26 shows a long list of challenges, barriers, future steps, and six milestones that remain. The reviewer questioned if there is enough time and budget to complete them all, and if so, whether the project will be completed on time.

Reviewer 5:
The reviewer reported that the project is one that is well planned and executed, and is leading to the development of alloys that can be integrate into Caterpillar's product line. One concern the reviewer noted is that Caterpillar has moved away from the on-highway market. Application of these improved materials may not obtain significant fuel economy improvement in off-road vehicles. The reviewer suggested the results from this project could be used by many engine manufacturers for on-road applications.

The reviewer said future research focusing on the selection of the best material option should continue. Also, the reviewer suggested the project team should investigate novel (phases) approaches for precipitate strengthening and heat treating should be investigated to enhance the properties.

Reviewer 6:
The reviewer noted plans for research over the coming year are ambitious and include modeling, experimental validation and casting. Several new developments are planned that include developing experimental process for increasing the solidification rate of step block castings using a new supplie , developing new models, and demonstrating component design. The reviewer questioned if there are there sufficient resources to complete all tasks.

Reviewer 7:
The reviewer indicated the project team has lots of work ahead of them.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer explained that increased cylinder pressures and reduced cost for engines and engine materials do support the DOE petroleum reduction goals (as the work will increase engine efficiency and push implementation into production). Power density/package size will be a major benefit of this work for the HD engine applications (475 horsepower [hp] from 9 liter [L] instead of 15 L).

Reviewer 2:
The reviewer reported that the project is developing higher strength Fe metals to enable higher temperature, pressure and efficiency of combustion. Once commercialized, this directly results in reduced petroleum consumption.

Reviewer 3:
The reviewer stated this project's focus on the development of higher power density engines can lead to a reduction in engine size and a more efficient engine

Reviewer 4:
The reviewer indicated that the project is geared towards developing higher efficiency engines with improvement in component strength using conventional casting techniques.

Reviewer 5:
The reviewer commented that both the pace of innovation and the materials developed using this approach will benefit the manufacturers in addressing their requirements for high-strength/temperature materials going forward

Reviewer 6:
The reviewer observed decreasing mass via higher strength and allowing higher peak cylinder pressure.

Reviewer 7:
The reviewer noted the following quote: "Advanced materials that are lighter and/or stronger are essential for boosting the fuel economy and reducing emissions of modern vehicles while maintaining performance and safety."

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that this project is appropriately funded and staffed.

Reviewer 2:
The reviewer indicated the project team is on track, but there are a lot of deliverables on the horizon for the project team.

Reviewer 3:
The reviewer stated that the he resources appear to be sufficient to complete the work described on the timetable outlined.

Reviewer 4:
The reviewer said that funding appears to be sufficient and did not note that funding was lacking

Reviewer 5:
The reviewer noted the project is sufficiently funded and well balanced between industry cost share and government funding.

Reviewer 6:
The reviewer indicated that sufficient information on distribution of funds was not provided, but it appears that the resources have been adequately allocated to enable the completion of tasks.

ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications: Mei Li (Ford Motor Company) - pm060

Presenter

Mei Li, Ford Motor Company

Reviewer Sample Size

A total of 12 reviewers evaluated this project

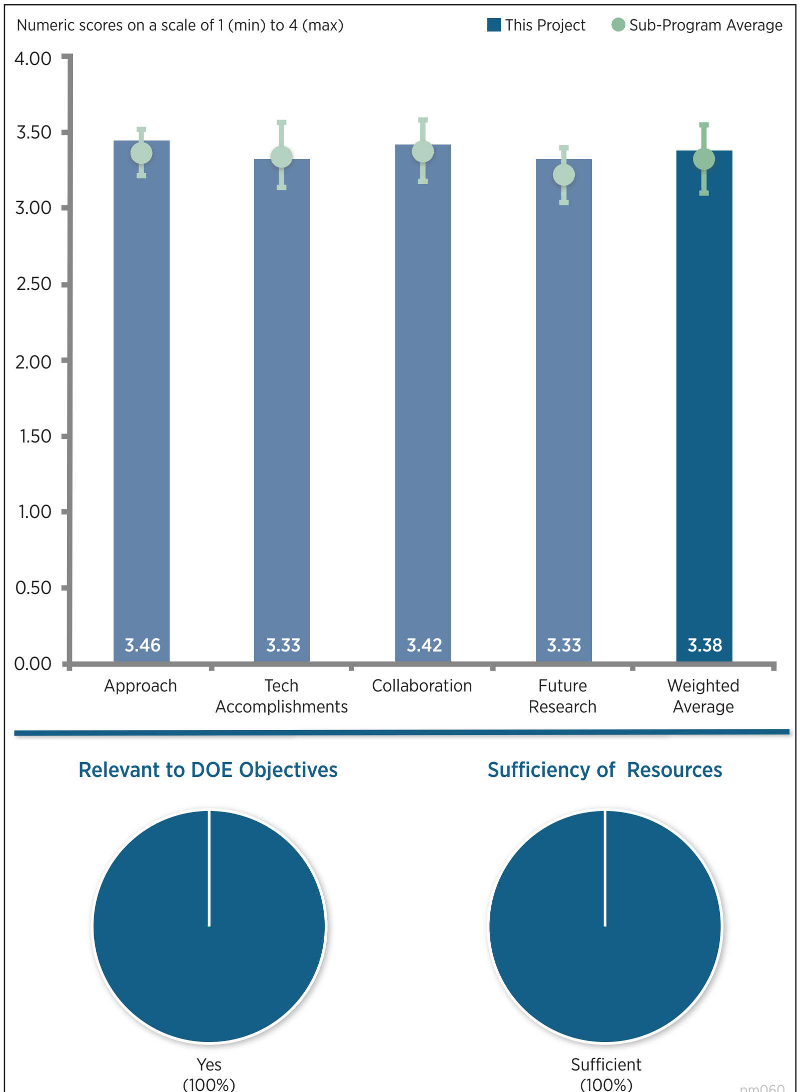

Figure 7-8 – ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications: Mei Li (Ford Motor Company) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer emphasized that the presentation was impressive. The alloy design approach was effective, driven by the awareness of the need for both a stable precipitate strategy (via slow diffusers) and adequate volume fraction of strengthening precipitate(s) at the target temperatures. A higher Cu alloy was chosen to achieve adequate volume fraction of strengthening phases. The reviewer reported the dual strengthening precipitate strategy was impressive and interesting. The two stage heat treatments seem necessary, but will add cost, the reviewer commented.

Reviewer 2:

The reviewer commented that the reputation of both Mei and the project team are well established. In addition, the approach to the alloy development is reasonably well thought out and appears to be ideal for the focus, which is an incremental increase in critical cast Al properties for a specific Ford engine block. The reviewer praised the computational approach presented early on that illustrates the desired magnesium (Mg) and Cu levels for strength optimization.

Reviewer 3:

The reviewer pointed out that the project team did good work on identifying and quantifying the baseline compositions and the roll of precipitates. The reviewer suggested it would add to the presentation if the impact of a successful completion was quantified in impact on an engine. The reviewer questioned how much lighter is the engine when this technology is deployed and how does that weight change effect overall efficienc . The reviewer commented that the Cu and Mg diffusivity work is impressive and thought there was a nice presentation of the requirements and expectations.

Reviewer 4:

The reviewer said the approach includes a focus on multiple components to improving Al alloy performance including precipitation strengthening, grain boundary strengthening, and solute strengthening. The reviewer mentioned the approach appears clearly based upon previous developments in the technology area, specifically aimed at achieving target properties and that the project also includes clear plans for application of project results to next-generation products.

Reviewer 5:

The reviewer indicated the approach seems appropriate to meet the objective to develop a new class of advanced, cost competitive Al casting alloys with 25% greater strength compared to A319 or A356 alloys for high-performance engine applications. In addition, the approach includes ICME tools for accelerating the development of new materials and processing techniques, as well as to identify the gaps in ICME capabilities.

Reviewer 6:

The reviewer noted the project team's approach to the Al alloy design is logical, uses sound metallurgical and scientific processes, and addresses the key material properties necessary to increase engine thermal efficien . The project team has a clear grasp of the science behind improving the properties of these lightweight alloys. The reviewer reported that the team is conducting extensive development of proposed alloys to optimize their composition and resulting properties.

Reviewer 7:

The reviewer concluded the approach seems effective in selecting an alloy and the current castability assessment activities seem sufficient

Reviewer 8:

Overall, this reviewer noted that the project appears to be well-designed to accomplish the goal of developing stronger alloys at room temperature and high temperatures that exceed DOE yield strength targets. The presented work appears to be experimental with analysis of experimental results. The reviewer cautioned that the role of how ICME was used to guide the approach is not clearly stated or clear. It appears that ICME was used to develop the alloying and heat treatment process, but was not specifically described. Slide 32, just before the summar , showed how ICME will be used to develop a commercial process using the project results with a 15-25% development time savings estimate. Otherwise, the project presents a comprehensive study of how to design (structure, heat treatment, cooling rate control) and quantify alloys to meet the DOE targets (tensile strength, fatigue strength, etc.). The reviewer indicated that cost analysis to ensure an incremental increase within 10% was mentioned, but apparently with no work in this past year. This reviewer further explained that the cost model was implied to have been developed before and will be refined next yea .

Reviewer 9:

The reviewer noted that ICME allows for cost effective design of materials with big computing resources now available to the industry. For example, many variables for precipitates can be modeled to accelerate the selection of alloy components. The reviewer concluded this type of approach is much improved versus the trial and error methods of the past.

Reviewer 10:

The reviewer mentioned a common approach of employing ICME techniques to select initial alloy compositions is employed. Initial alloy compositions include varying contributions from silicon, Cu, and Mg (later X and Y). The reviewer noted new heat treatments are then employed to enhance precipitation hardening followed by microstructural characterization and mechanical testing.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted overall, the accomplishments are very good for this project. The project team's heat treatment and aging process results in increased strength with thermally stable precipitates, which is a good accomplishment. In addition, the project team has seen good results in achieving the microstructure desired for the necessary mechanical properties. The team has achieved the DOE target for basic properties of tensile strength at room temperature and high temperature, and is working on thermomechanical fatigue. This person said the project team has increased thermomechanical fatigue performance over baseline alloys and has seen good improvement in fatigue strength.

Reviewer 2:

The reviewer pointed out the project has already met and/or exceeded DOE targets for performance of yield strength and ultimate tensile strength for several alloys, so efforts now are targeting further improvements. This was achieved through a combination of compositional changes as well as processing, particularly heat treating, improvements. This person indicated that the project also completed the plans for the block bulkhead and the gasoline turbocharged direct injection (GTDI) cylinder head, tying together a future application for the results of this project. The reviewer said that the only concern on accomplishments is related to timing. At last year's AMR, the project was reported as 70% complete compared to 80% complete reported this year. The project was scheduled for completion by February 2016, which has now been extended to November 2016.

Reviewer 3:

The reviewer reported the project objectives include developing a new class of advanced Al casting alloys and demonstrating the power of ICME for accelerating materials and processing development. This person indicated that the project is making very good progress on both of these objectives. Yield, tensile and fatigue strengths are above target values. The reviewer said modeling of casting and heat treatments feed predictive results for material properties and lifetimes have served to optimize the development process and reduced development times.

Reviewer 4:

The reviewer said that the room temperature and 300°C high-temperature properties were met in the as annealed materials, which was an impressive accomplishment. However, the averaged 300°C ultimate tensile strength (UTS) data after 100 hour exposure appeared to be lower than the DOE targets. Also, the 300°C exposures were shown after only 100 hours, whereas the other two cast Al projects in the same session showed data after longer exposures of 200 hours. The reviewer noted that leads to the question of how stable are the alloy properties at 300°C. This person said it would be useful to see properties after longer-term exposure in the 2017 meeting. The reviewer pointed out that the improvements in 120°C fatigue strength for the new alloys were very promising. The reviewer stated that overall this is very nice work.

Reviewer 5:

The reviewer indicated the creation of the alloy and the required heat treatment within a single project is a lofty goal, and the project team is doing this as well as looking at the influence of cooling rates of the casting. This person noted it is nice that the project team is covering all of the issues associated with market deployment.

Reviewer 6:

The reviewer noted the project finished the design of new cast Al alloys (H16 and H17) that met DOE requirements for high temperature and fatigue strength. The new alloys with the optimum heat treatment process achieved greater than 20 MPa fatigue testing above the baseline at 120°C. This person reported that out-phase thermo-mechanical properties demonstrated thermal stability of the new alloys at low strain range and long life regime.

Reviewer 7:

The reviewer remarked that the alloy selection seems complete and data generated for designers seems sufficient

Reviewer 8:

The reviewer indicated the project is leading toward the development of materials that can be used in the engine block bulkhead and GTDI cylinder head. This person noted the design of alloys was completed, alloys meet DOE Targets and there is a need to demonstrate performance in the target application.

Reviewer 9:

The reviewer noted the project is approaching its deadline but is only 30% completed.

Reviewer 10:

The reviewer reported that the presentation shows that it is 30% complete, which is the same as 2015. The reviewer concluded that this was just a typographical error based on the accomplishments and the fact that the project ends in November 2016. The reviewer noted that funding numbers were not accurate or updated between 2015 and 2016 presentations, which made it unclear where spending was last year to compare to progress. The presented results describe the process and results to better understand the structure, heat treatment, and cooling rate control of the developed alloys. The reviewer observed that the project determined aging needs for particle distribution and stability. This person stated that progress towards meeting DOE cost targets was not described and it is unclear how ICME was used throughout project and how or what ICME gaps were identified

Reviewer 11:

The reviewer said the presentation itself provided little information such that the reviewer must have missed a key point made orally during the presentation. This reviewer re-evaluated the slides, but the slides did not provide insight. The reviewer questioned why the program is approaching its completion date and is only 30% complete. The reviewer indicated there may well have been a sound reason for this, but did not recall what it was. This person noted the presentation itself was long on introductory matter and general, if nuanced, commentary on accomplishments and future work that was to validate models and identify gaps. The reviewer concluded that presentations with this level of detail could be generated long before a program even begins. More project-specific information on what is actually being pursued would be very welcome, even when acknowledging that the project is having success in the stated goals. The reviewer pointed out this project team is too talented not to provide seminal commentary on cutting-edge ICME approaches.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted he team has the right combination of collaborating skill sets. This is as good a team as one might find in this topic area

Reviewer 2:

This person commented that clearly Ford and Alcoa are communicating well and working in a synergistic manner.

Reviewer 3

The reviewer pointed out that Alcoa (materials expertise), Nemak (Ford engine supplier), Magma (alloys) and University of Michigan (UM) (simulation and experimentation support) are project partners and their roles in the project seem very appropriate leveraging their respective core competencies.

Reviewer 4:

The reviewer said that the team appears to have an appropriate balance of suppliers and academia in combination with the OEM prime contractor. A slide explicitly describing the collaborations would be helpful for reviewers to fully judge the quality of the collaborations. This reviewer commented that Ford is collaborating internally to move this alloy to a 2020 release for production, which is extremely important.

Reviewer 5:

The reviewer stated the project has a highly qualified team with substantial pre-existing resources and capabilities

Reviewer 6:

The reviewer stated the project has an impressive list of collaborators, all of whom were brought on for their potential involvement in the next steps (deployment and use), their capabilities, and/or their facilities. The collaborators include Alcoa, Nemak, MAGMA Foundry, and UM. The reviewer noted the collaborators roles were explained in previous year’s presentations, but not as clearly in this year’s.

Reviewer 7:

The reviewer observed that there seemed to be good collaboration with UM for transmission electron microscope (TEM) and atom probe analysis. This person noted the roles of Alcoa, Nemak and Magma were not clear.

Reviewer 8:

The reviewer indicated that collaborators Alcoa, Nemak, MAGMA Foundry Technologies, and UM, were mentioned but their roles were briefly described. This person suggested that the roles of the collaborators can also be logically-inferred. The fact that the project has made a lot of progress implies the partners are collaborating well.

Reviewer 9:
The reviewer said team members include several industry members and one academic institution. This person suggested the addition of a national laboratory should be considered to gain access to their computing capability.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the modeling of phase transformation kinetics is important and exciting.

This person stated that the project team is committed to identifying the gaps in the microstructure and property models, but the team does not have a loop to address them.

Reviewer 2:
The reviewer reported the project is scheduled to be completed in November 2016. The plan is to demonstrate inclusion of successful alloys in block bulkheads. The alloys will also be used under another program (i.e., Ford's GTDI Engine) under a separate DOE contract. Ford's plans appear to focus on inclusion of these advanced alloys into available products in 2020, with incorporation into the GTDI engine likely first. The reviewer voiced a concern that there are a number of activities remaining to be completed by the end of the project in November 2016, so time may be tight.

Reviewer 3:
The reviewer commented that the stated goal of a possible application of the new alloy for the 2020 model year was intriguing. The plan to demonstrate a new alloy on a new GTDI I4 architecture was impressive, and indicates a serious interest in bringing the new alloy(s) to market eventually. This person said it will be interesting to see the final cost analysis with the added heat treatment step

Reviewer 4:
The reviewer indicated that future research includes demonstrating the performance of new alloys in block bulkhead and Ford GTDI cylinder head and that bench testing has been scheduled.

This person stated that the project will appropriately assess the cost of the new alloy compared to the baseline alloys (A319 and A356).

Reviewer 5:
The reviewer reported that the project team has a logical list of future work activities to complete the project this year. The team will demonstrate casting of actual engine components in this future work, which is very appropriate and useful for eventual commercialization.

Reviewer 6:
The reviewer explained that the plans for completion of project including demonstration of developed alloys in cast components (cylinder heads) appear to be on track.

Reviewer 7:
The reviewer indicated the future plans appear to address most of the remaining challenges. However, it is unclear how the project contributes to determining ICME gap analysis. This reviewer indicated that the plan for refining the cost model and how the cost impact will be determined was not described. Especially because the project ends in November 2016, the reviewer questioned the remaining effort and cost based on inaccuracies of stated percent progress and budget.

Reviewer 8:
The reviewer commented that the gaps in the ICME tools are not clear from the presentation. This person said these remain on the future work slides but one would suspect that these areas of improvement have been discovered along the way.

Reviewer 9:
The reviewer indicated the project demonstrated performance of alloys and the target is in 2020 for commercialization into product line. This reviewer also observed a significantly accelerated approach versus conventional material development timelines. The reviewer noted that focus on commercializing lighter weight high-pressure diecast (HPDC) block bulkhead and Ford GTDI cylinder head appears to be a good application of this material.

Reviewer 10:
The reviewer referenced prior comments and indicated that the integration of wide-ranging ICME models is not readily identifiable from the work that was presented. This person suggested that for a program that is so heavily leveraged by DOE funding, the discovery and application of ICME tools should be a key focus area, allowing that Ford has intellectual property that it will want to protect. A program like this is most beneficial to DOE goals when some element of shareable discovery is made public. From a program-specific standpoint, the results for different processing approaches to the H16 and H17 alloys are not overly compelling. The overlap in the limited data points indicates that some statistical significance exists that would allow the program to conclude that the claimed improvements are real, but a more strict presentation of the data that outline this significance would help immensely. The reviewer stated that additionally, for a program at this stage it is difficult to believe that no previous reviews provided critiques that were worthy of addressing in the presentation and that no such information was provided.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer agreed that advanced cast alloys are certainly germane to DOE objectives vis-à-vis the transportation sector. Increasing both strength and stability of lightweight cast alloys, which this program is accomplishing, is a definite step forward

Reviewer 2:
The reviewer stated that the increase in strength will allow decreased mass in the casting at a similar temperature and pressure during service.

Reviewer 3:
The reviewer said the project is aimed at improving the strength of Al alloys, demonstrating ICME tools for materials processing, developing cost models, and conducting technology transfer and commercialization planning for deployment of the new alloys. The result of this project should be higher performance Al alloys allowing for higher efficienc , clearly of relevance to the DOE objectives.

Reviewer 4:
The reviewer commented that the development of an alloy that meets the challenging DOE goals enables design of much higher efficiency engines in the future

Reviewer 5:
The reviewer indicated that high-temperature and pressure metal alloys enable high-efficiency internal combustion engines and therefore, enable petroleum displacement.

Reviewer 6:
This person reported that new high-temperature alloy work for lighter weight and increased efficiency engines is directly relevant to DOE petroleum reduction goals.

Reviewer 7:
The reviewer reported the alloy has been improved with use in the design of a new cylinder head and efficiency improvement is expected.

Reviewer 8:
The reviewer pointed out that the project is developing higher strength Al alloys to enable higher temperature, pressure, and efficiency during combustion. Once commercialized, this directly results in reduced petroleum consumption.

Reviewer 9:
The reviewer acknowledged that lighter weight and higher performance propulsion materials being developed lead to more efficient and lighter vehicles

Reviewer 10:
This person observed that overall cost of materials and component development may increase but the new alloys should lead to lighter weight vehicles and higher efficienc .

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the project is on track for completion at the stated time, and the amount of work completed seems to correlate with their schedule.

Reviewer 2:
The reviewer said no indication was made that the resources are not sufficient, and the project team appears to have made significant progress under existing funding

Reviewer 3:
The reviewer indicated that the budget seems appropriate for the presented project scope. FY 2016 budget is $1.3 million to focus in on demonstrations and total DOE project funding is $3.24 million with project team contributing $1.39 million in cost share.

Reviewer 4:
The reviewer said the project appears to be appropriately funded, based on the technical achievements displayed.

Reviewer 5:
The reviewer reported funding appears to be sufficient and did not note funding was lacking

Reviewer 6:
The reviewer said that the project remains on schedule and funding should continue on the originally planned timeline to ensure commercialized product arrives in the market in 2020.

Reviewer 7:
The reviewer noted the project spending was not addressed; however, it appears that resources are sufficient

Reviewer 8:
The reviewer noted the question of timeliness still remains. The program is considerably lagging a straight-line use of funds if it is scheduled to end in five months

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Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines: Mike Walker (General Motors) - pm061

Presenter
Qigui Wang, General Motors

Reviewer Sample Size
A total of eight reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

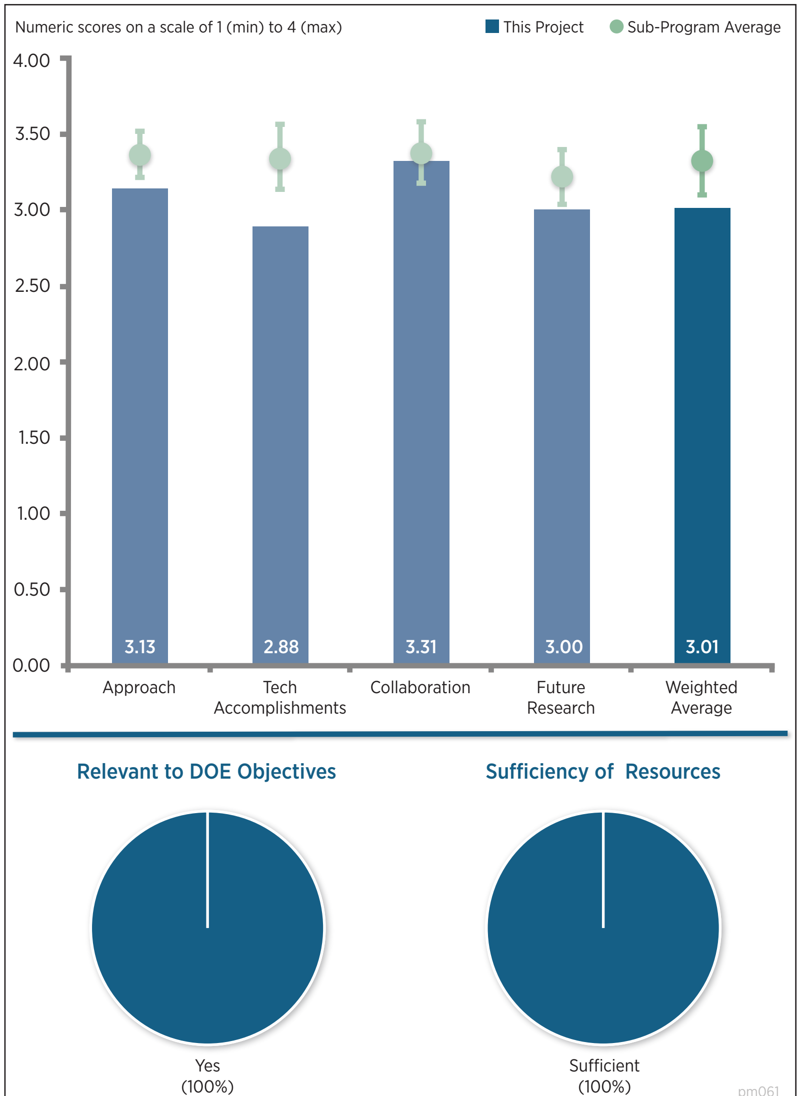

Figure 7-9 – Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines: Mike Walker (General Motors) - Propulsion Materials

Reviewer 1:
The reviewer stated the approach is logical and appropriately thought out. The project team is focusing on high-temperature strength and fatigue characteristics of these lightweight alloys, and both characteristics are critical for engine durability. This person pointed out that the examination of higher strength lightweight alloys is important to achieve higher peak cylinder pressures and engine efficienc . The project team is considering the effects of alloy processing and microstructure on the key material properties of relevance to engine structures, which is quite appropriate, commented the reviewer.

Reviewer 2:
The reviewer observed that the approach of using density functional theory (DFT) models for alloy concept development and alloy selection, button castings for structural and physical properties is solid. This person stated that the modification to the approach outlined in the critical assumptions and issues slide is a reasonable adaptation to the original approach.

Reviewer 3:
The reviewer stated that the focus for the approach has been improving high-temperature strength to improve engine performance. The key element of the approach for 2015-2016 was clearly identified as analysis of two new alloys. This includes a careful look at cast defects because they have significant impacts on ultimate fatigue. The reviewer noted that the approach, as presented, included a matrix-type approach across processing, structure, and properties, in an attempt to provide the level of in-depth analysis needed.

Reviewer 4:

The reviewer commented that was a nice graphic in the presentation to explain the approach and strategy on Slide 5. In addition, this person said there was a well explained scope and an alignment with the goals. The reviewer suggested there could be an increase in merit by surveying a wider view of the material options.

Reviewer 5:

The reviewer commented that the down selection approach and evaluations to date seem appropriate for the goal, but nothing overly transformational is being shown. This person said just a sound approach to alloy improvement through relatively minor precipitate structures was shown. The program is progressing with regard to ongoing evaluations, but despite the detailed analyses there is not yet an overly compelling reason to think that the Q alloy will be entirely successful. The reviewer suggested it would appear that the Rio Tinto alloy is more promising despite the low ductility. Regardless, the foundation is being established for continuing alloy development efforts that begin with atomistic/DFT simulations and end with component trials. The reviewer stated that the results from the dispersoid element trials will be of great interest with regard to the stated property targets and cost modeling.

Reviewer 6:

The reviewer reported that the computational approach was very broad, but narrowed to a strategy centered on the Q phase. In addition, focusing on casting defects and fatigue properties was of value, commented the reviewer. This person suggested that tit would have been helpful to have a slide explaining why the Q phase was selected for a 300°C strengthening strategy.

Reviewer 7:

The reviewer mentioned it would be interesting to evaluate the stability of the elevated temperature property response at 200 hours. This person questioned how stable are the properties for the Q alloy.

Reviewer 8:

The reviewer suggested that the presenter better define the additive selection process to clarify the additives needed to improve material performance. The project may actually achieve the end results but there are better methods to identify these alloys such as ICME. The reviewer pointed out that this project used ICME earlier, and connecting these results to the previous ICME research would help clarify the selection process. This person commented that the virtual casting approach to reduce the weight of the cylinder head is innovative.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that it appears all go/no-go points to date have been successfully passed. The project has appeared to down-select from six alloys to one, which is a Q phase alloy. This person pointed out that the Rio Tinto Alcan (RTA) alloy met all DOE high-temperature requirements, but ductility was an issue. Ultimately, new alloy concepts were generated. The reviewer indicated there were some setbacks, but the project appears to have retrenched and, based upon what the team had learned so far, moved ahead with the new concepts.

Reviewer 2:

The reviewer noticed that the status of any significant breakthroughs is not coming across in the presentation, although to be fair this type of effort is not at all straightforward. This person said that the project team is to be commended for identifying approaches that simply did not pan out along with successes, as there are bound to be both in alloy development that draws upon multi-scale approaches. The reviewer commented that the reasoning behind the alloy selection process is sound.

Reviewer 3:

The reviewer observed that it is impressive that the project team has already created 100 cylinder heads with the new material. This is very fast progress on design to market timing. However, the reviewer noted the project seems more iterative than transformative. The reviewer suggested it would add merit if the project team made some estimation of the actual impact on the change in weight if this project is successful.

Reviewer 4:
The reviewer stated that the project has established a viable approach for selection of new materials to meet DOE targets. In executing the work the project has generated a substantial amount of data and knowledge but has yet to identify materials with an acceptable combination of strength and ductility. The shift to exploring dispersoids may yield better results. This person commented that project milestones have been met.

Reviewer 5:
The reviewer pointed out that in past work, the team has conducted a systematic exploration of prospective alloys with differing precipitate structures, and down-selected to the Q phase precipitate. The team has now validated the basic characteristics and microstructure models of the precipitates, which appears to be good science-based work. This person commented that this has led to the down-selection of a candidate precipitate for further development. The reviewer noted that all of these are good accomplishments.

Reviewer 6:
The reviewer observed that an alloy has been identified which meets the ta gets in high-temperature mechanical properties. In addition, strength model prediction and optimization looks promising for the future.

Reviewer 7:
The reviewer commented still no final alloy configuration has been identifie This person suggested that some of this information may be corporate confidential. Howeve , it is difficult to determine if the project is leading to success without this information.

Reviewer 8:
The reviewer reported that it appears that a high volume of thoughtful computational and experimental work has been conducted, and improvements in alloy properties have been achieved. However, the results indicate that that the primary approaches to creating a stable, higher strength alloy at the target temperature has not been successful. The reviewer indicated that the mechanical property targets for 300°C have not yet been achieved, nor were there strong indications in the presentation that the present alloy design approach will eventually achieve such targets.

In addition, the introduction of the RTA alloys seems to confirm that the Q or Theta Q alloys will not achieve targets. However, the RTA alloys do not have sufficient ductilit , as was pointed out by the presenter. The reviewer said that the definitions of coarse and fine structure were uncle . The reviewer mentioned it was also unclear why other strengthening strategies were not evaluated when the Q phase emphasis did not prove adequate for 300°C properties. The reviewer observed it was stated that hundreds of thousands of crystal structures were analyzed by high-throughput DFT. This person suggested it would be interesting to know how those analyses along with the calculations of elemental segregation and interfacial strengthening predicted success with the Q phase at 300°C. It will be of value to the ICME community to see what properties or advantages were predicted for the Q-phase through computational approaches, and then compare to actual measured properties or improvements in properties versus baseline materials.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated that the project includes a long list of collaborators: Questek, Northwestern, American Foundry Society, Fred Major, Camaneo Associates, and Massachusetts Institute of Technology (MIT). This person pointed out all have clearly identified roles under the project

Reviewer 2:
The reviewer noted that the team has a good balance of collaborators including OEMs, a material supplier, academics, and ICME experts that provide the right expertise. The team is taking advantage of this expertise through the distribution of activities under GM’s leadership.

Reviewer 3:
The reviewer stated that the project is comprised of a strong set of collaborators.

Reviewer 4:
The reviewer indicated that all collaborators appear to be working together.

Reviewer 5:
The reviewer commented that including MIT was a good addition with the academic community. This person pointed out the project could still use a national laboratory to improve the team's expertise and capabilities. National laboratory expertise could add computational capabilities to the team.

Reviewer 6:
The reviewer observed that the project team is both diverse and talented in a number of specific areas that are a benefit to the proposed e fort. This person suggested that specific roles and responsibilities are not coming across in the presentation, and the amount of work being carried out by Questek, for instance, is not afforded an appropriate level of significance. A great deal of the work being done was not identified until the response to the reviewer comments section.

Reviewer 7:
The reviewer said that there are clear ties to GM and well-grounded in what is necessary to commercialize. This person pointed out it is surprising that GM did not have a clear test procedure for material aging, or that it was not shared. The reviewer commented there was no clear tie between aging time and product requirements for durability and useful life.

Reviewer 8:
The reviewer commented that there appear to be very strong collaborations with Questek for the computational activity; however, the roles of the other partners were not quite clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that the presentation included a number of specific activities planned for the rest of 2016 and for 2017. The list makes reasonable sense, assuming that at least one alloy can be developed to move all the way through the test and development process. This person pointed out that should there be a setback; the project team will need to stay flexible, as they showed in 2015-2016

Reviewer 2:
The reviewer commented that the future work plan looks reasonable and appropriate, with casting trials of the down-selected alloys and associated testing/analysis. This person said that the work plan tasks are appropriate to complete the work by the end of FY 2017.

Reviewer 3:
The reviewer stated the future work slide details the planned work for 2016 and 2017 and this is a reasonable approach for achieving project goals.

Reviewer 4:
The reviewer commented that some level of confidence that the Q alloy will be successful in meeting all of the targets is still in question, but the project team is pushing forward with planning for full component trials. This person indicated that the project team is making interesting and scientifically significant progress, but commente that were a major GM stakeholder would want to see more concrete results that the project team is on the absolute correct path prior to moving from evaluations to the practical component test phase.

Reviewer 5:
The reviewer suggested that comments regarding the utility of high-throughput DFT calculations, the Open Quantum Materials Database (OQMD), would be useful.

Reviewer 6:
The reviewer indicated that the future work was not well presented and passed quickly. This person noted that in reviewing the presentation the project team has a path forward but it is still narrowly focused.

Reviewer 7:
The reviewer observed that the future effort could be clearer if the specifics were provided. This person stated with the given information, it is not clear that this project will achieve the end result with the remaining funding and the established approach.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that this project addresses the material issues facing LD engine designers as they push the limits of efficienc , with resulting achievement of DOE petroleum reduction goals. Increasing engine materials capability (peak cylinder pressure and temperature) are critical considerations for raising engine brake thermal efficiency that can often be overlooked

Reviewer 2:
The reviewer stated that alloys found in the study will lead to efficiency and weight reduction improvements in internal combustion engines.

Reviewer 3:
The reviewer commented that the project is specifically relevant to DOE and VTO objectives, as it is aimed at moving toward DOE materials targets to allow for increased performance and efficiency for light-duty spark ignition engines.

Reviewer 4:
The reviewer mentioned that developing improved alloys will allow more aggressive combustion strategies to enable higher engine efficiencies

Reviewer 5:
The reviewer said that the target material will provide the capability to increase engine efficienc .

Reviewer 6:
The reviewer pointed out that the project strives to achieve DOE goals for lightweight materials that tolerate higher pressures and temperatures in light-duty vehicles.

Reviewer 7:
The reviewer indicated that the program follows the stated targets of cast lightweight alloys and those metrics are being used to evaluate progress.

Reviewer 8:
This reviewer commented that efficiency increases would push higher mass materials if this option was not available. The reviewer further explained that the casting can be minimized using these improved materials properties, which would be lighter as well.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that funds appear sufficient, at least at this point. It is unclear how much of the overall DOE funding has been received, but with the shrinking overall Propulsion Materials funding, there could be issues if significant funding is required in F 2017.

Reviewer 2:
The reviewer observed that the team has moved through the down-selection phase, and although there is

considerable work to be done the team appears to be progressing well against the proposed timeline with completion in September of 2017.

Reviewer 3:

The person stated that the project team is on target and meeting milestones.

Reviewer 4:

The resources appear to be sufficient to complete the work as described over the timeframe of the project

Reviewer 5:

The reviewer noted funding seems appropriate to execute this approach, given the previous ICME work. This person pointed out that it appears that the remaining funding will mostly be used for durability testing.

Reviewer 6:

The reviewer observed that sufficient information on the use of project resources was not provided. This person suggested the project appears to be adequately funded.

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High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines: Amit Shyam (Oak Ridge National Laboratory) - pm062

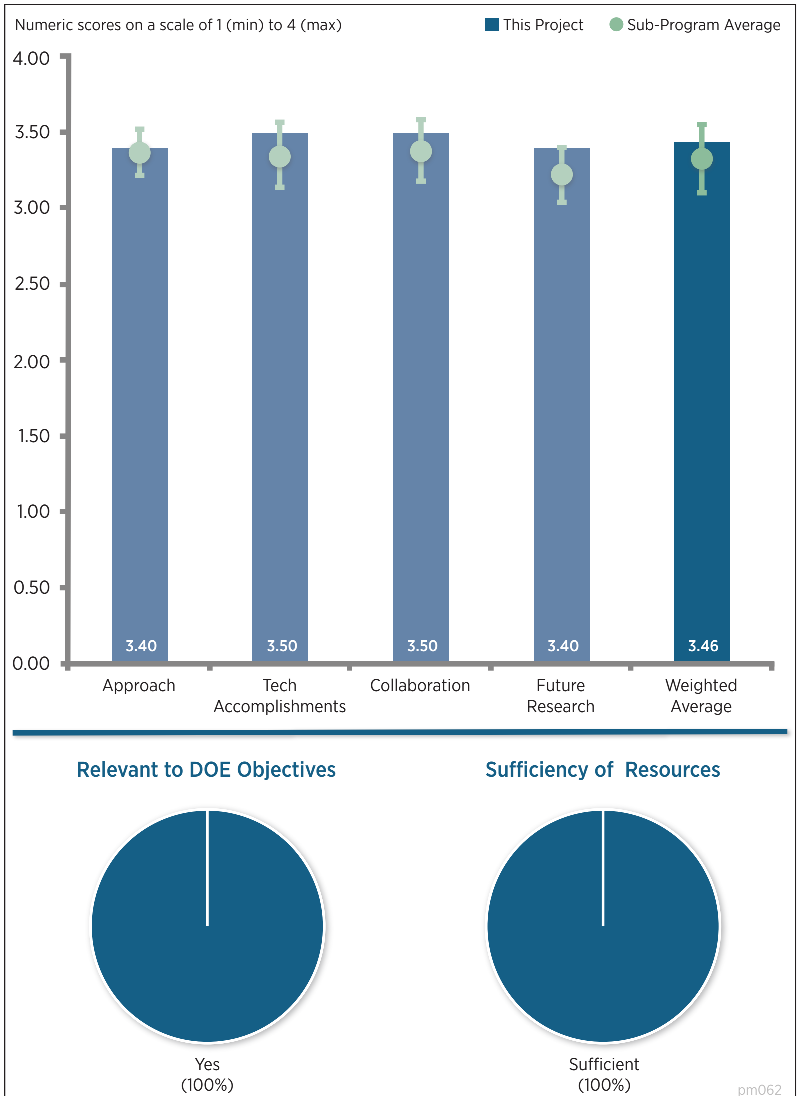

Figure 7-10 – High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines: Amit Shyam (Oak Ridge National Laboratory) - Propulsion Materials

Presenter
Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer reported that the results of this alloy design study are impressive.

Reviewer 2:
The reviewer noted that the approach seems to be appropriate and focused on accomplishing project objectives. The project is aimed at reducing the cost of improving the performance of engine materials through ICME. The reviewer observed that in particular, project efforts focus on balancing the need to satisfy several properties simultaneously.

Reviewer 3:
The reviewer commented that there are very interesting results thus far, and the program appears to be proceeding successfully. With a focus on the microstructural stability, however, more emphasis on the practical response of the alloys following extended aging would be very beneficial. This person said all targets are met, but questioned what the effect is on precipitate size and aspect ratio following times that are more reflective of engine lifetimes rather than minimum qualificatio targets. The reviewer asked if the results that are being seen by the project team still valid. The reviewer noted that the microstructures and schematic of Slide 8 do not really close the argument.

Reviewer 4:
The reviewer observed that the project has two goals; the first is to determine an appropriate high-temperature Al-alloy with the target properties through an ICME approach, and the second to determine the gaps in the ICME approach to discovering a new appropriate alloy in this specific case. The reviewer stated that overall the approach is reasonable, but ultimately, as the project team suggested, does not work well due to the current lack of knowledge and models for the microstructure evolution. This person suggested that the technical accomplishments shown in the presentation indicate that the necessary knowledge can be achieved by atomistic simulations.

The reviewer mentioned that presumably, the ICME approach will still be used to evaluate the performance versus cost trade-off of the different candidate Al-alloys, which is equally as important as the discovery of new alloys.

Reviewer 5:
The reviewer stated that the researchers have successfully implemented an iterative ICME approach consisting of modeling to suggest material composition, casting and mechanical testing, component casting and testing. The focus of the results is on elevated temperature mechanical properties and castability and hot tear resistance. This person indicated the project team has recognized the limitations of this approach, including functionality in cylinder heads and unknowns including thermal conductivity, corrosion resistance, residual stress and cost.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that the technical accomplishments are substantial. These include developing computational capability to predict useful elemental combinations, generation of high-temperature alloys that exceed tensile strength targets at 300°C, confirmation of hot tear resistance, and proof of microstructural stabilit .

Reviewer 2:
The reviewer indicated that the team has utilized some powerful tools and practical approaches to alloy casting to provide broad test matrices for evaluation. This person observed that this is a real plus of the program's presented results to date.

Reviewer 3:
The reviewer pointed out that the project has identified improved alloys, and is now casting components. To date, the high-temperature alloy, at 300°C, exceeds the technical target by more than two times. It also has exceptionally stable microstructure, which was confirmed through testing at Brookhaven National Laborator . This person observed the project then took what it learned to develop computational capabilities to predict microstructure results for other material combinations, which can be used for future stabilization efforts. This approach has identified which elements provide good high-temperature stabilit , and which ones do not. The reviewer stated that to date, the project has cast about 30 alloy compositions using the project's concepts and that most of the high-temperature alloys appear to have very good hot tear resistance.

Reviewer 4:
The reviewer noted a strong understanding on improving high-temperature strength in Al alloys was shown in the presentation. This is achieved through control of the mobility of the semi-coherent interfaces of the precipitates, thus controlling the precipitate size at elevated temperature. The reviewer noticed that from the modeling effort, it seems that several potential candidate Al alloys have been determined and the project is moving along well towards its objectives.

Reviewer 5:
The reviewer indicated that it was interesting use of DFT models to predict stable precipitates.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the project appears highly collaborative, with regular calls and face-to-face meetings. Partners (under a CRADA) include Fiat Chrysler Automobiles (FCA) and Nemak, plus collaboration with Granta MI, ESI North America, Flow Science, Magma Foundry, and Minco. All have specifically-identified roles coverin the project's needs, and there is significant cost-share. The reviewer noted that FCA has already indicated it will soon (within two years) incorporate an alloy from this project into an engine component for a higher efficiency engine.

Reviewer 2:

The reviewer indicated that researchers have engaged partners from automotive and manufacturing industries and collaborations appear to be working well.

Reviewer 3:

The reviewer pointed out that the actual contribution of team members was questioned in a past review, as shown in the responses to reviewer comments section, and the team responded that all members were contributing significantl . The reviewer reported that there is no reason not to believe this, but little concrete evidence was specifically addressed in the body of the presentation to put this concern to rest. There is certainly a group of highly regarded names from ORNL being acknowledged, but whether there is equally significant contributions coming from outside of ORNL must be taken on the statement of the presenter. That being said, the cost share provided to supplement the DOE share was considerably higher in this program than for other similar programs, so there is a clear collaborator presence, this person commented.

Reviewer 4:

The reviewer reported that collaboration with CRADA partners seem well established and organized. The large-scale castings by the CRADA partners will provide a nice comparison to the current results. This person observed some mention of other partners was made, though the amount of collaboration effort between those partners is unclear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer enthusiastically looked forward to the results of the larger heats and component trials.

Reviewer 2:

The reviewer reported that a number of specific activities have been identified for the remainder of 2016 an 2017. In particular, the project is looking at optimizing alloys for both technical and cost targets. The reviewer pointed out that additional elements need characterization, such as thermal conductivity, corrosion resistance, machinability, and residual stress. There will also be additional ICME modeling work to fill gaps in current capabilities. The reviewer observed that future efforts appear to culminate in preparation for large scale evaluation on an engine platform and development of a cost analysis and commercialization plan.

Reviewer 3:

The reviewer stated that the future plans are well thought out and were presented adequately at the review. The plans follow a logical progression to completion and include additional mechanical testing, attempting to understand those properties not addressed thus far including thermal conductivity, corrosion resistance and residual stress. The reviewer commented that also included are plans to refine the ICME approach, produce a gap analysis and a cost and commercialization plan.

Reviewer 4:

The reviewer indicated that the future work seems on-track with the proposed milestones in the project and the immediate work plans are well outlined. The microstructure stability characterization coupled with the casting evaluation will provide useful information between the structure and property relationships. This person has a slight concern in the down-selection of the new alloy composition, which was originally proposed as one of the future work plans to be done in the 2015 review. The ICME approach will give several alloys each with their pros and cons for the target key properties, but the reviewer predicts that the cost analysis will ultimately help reduce this to one. The reviewer suggests that the team put some more effort into the cost analysis coupled with the ICME approach sooner rather than later.

Reviewer 5:

The reviewer noted a good gap assessment in the ICME tools. This person questioned if any nondestructive testing improvements will be necessary in the final demonstration

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that the project is focused on improving alloys allowing for increased engine efficienc . Specificall , the project's goals include improved castability, high-temperature strength, and fatigue performance. Overall, the new alloy cylinder heads will have more than a 25% improvement in strength at a cost of less than 10% more. The reviewer pointed out these project objectives are all in line with the overall DOE VTO objectives.

Reviewer 2:
The reviewer noted that this project is aligned with the DOE objectives of petroleum displacement through the discovery and development of new Al alloys with high-temperature strength and fatigue properties. This person indicated this will enable the lightweighting of engine materials and consequently improved fuel economy.

Reviewer 3:
The reviewer observed that success of these alloys will lead to efficiency improvements in the internal combustion engine.

Reviewer 4:
The reviewer said the project directly addresses objectives set forth by DOE associated with material properties of tensile strength at high temperature.

Reviewer 5:
The reviewer indicated that the specific DOE ta gets for cast alloys are both stated and used to gauge progress.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the program is on target based on the progress to date, and the accomplishments as presented indicate that the next phase of the program that moves beyond alloy development and analysis is ready to commerce.

Reviewer 2:
The reviewer remarked no indication was made concerning the sufficiency of the resources, so they were assumed to be appropriate. This person said it should be noted that the presentation did not include any estimated DOE funding for 2017.

Reviewer 3:
The reviewer noted resources appear sufficient for the completion of this project. The largest cost seems to be in computational time or power, which is covered by the facilities at ORNL.

Reviewer 4:
The reviewer indicated that funding appears sufficient, although little information is provided regarding project costs.

Development of High-Performance Cast Crankshafts: Rich Huff (Caterpillar) - pm065

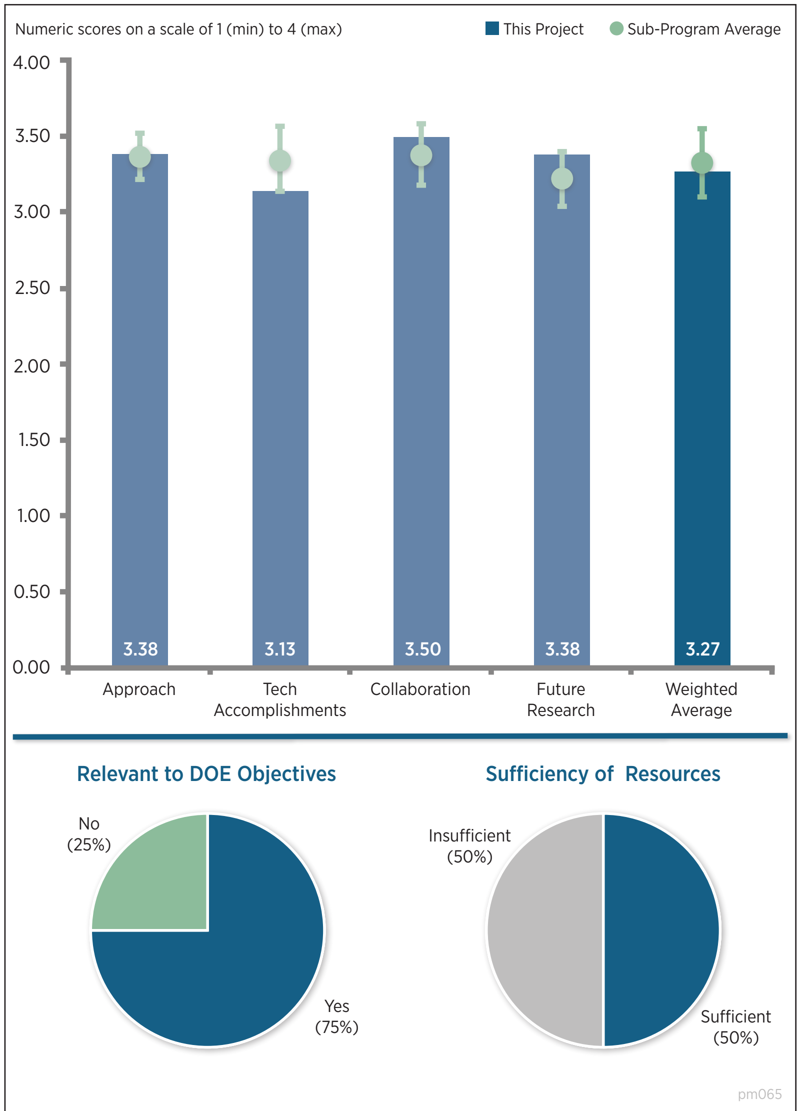

Figure 7-11 – Development of High-Performance Cast Crankshafts: Rich Huff (Caterpillar) - Propulsion Materials

Presenter

Rich Huff, Caterpillar

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said the work has a clear direction, is well documented with a nice flow chart of the selection and development process.

Reviewer 2:

The reviewer commented that proper targets were clearly defined and described for reviewers and indicated the approach appears to be sound. The reviewer pointed out that it would have been useful to see a simple castability study for some of the selected steels versus nodular iron, in order to give reviewers a sense of the relative castability of these steels. Casting and defect analysis of crankshafts, and comparison to the MAGMA software, was valuable.

Reviewer 3:

The reviewer indicated this is interesting work and has good progress. The reviewer referenced Slide 7 and requested an explanation regarding the allowable forecast design given the current alloy choice. The reviewer questioned if these are only composition dependent, or whether more is intended by this statement.

Reviewer 4:

The reviewer pointed out that using ICME allows faster development and lower cost alloy development. The reviewer said the project is also using APS at ANL to measure phase evolutions. The reviewer pointed out that use of Accelerated Insertion of Materials with ICME permits an accelerated iteration of material composition.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that good progress has been made in the first 30% of the project, but it seems that there are substantial processing hurdles to consistently cast clean steel cranks of complex geometry, particularly if hollow cranks are eventually cast to reduce mass. This person pointed out that casting defect modeling seemed to be very effective in predicting defect-prone areas. The reviewer noted that validation and calibration of ICME tools in subsequent years will be valuable. The vacuum assisted counter gravity (VACG) casting process is interesting, and cleanliness comparisons with other casting methods will be valuable, commented the reviewer.

Reviewer 2:
The reviewer said that progress toward the desired crankshaft is reasonable. In addition, alloy selection appears complete and sample crankshafts have been produced.

Reviewer 3:
The reviewer explained that 20 alloys were assessed but the yield strength target was not met. The reviewer pointed out the project casted a prototype steel crankshaft that used one of the highest potential alloys to determine how close to target it was and established a baseline. This person indicated crankshaft results were even better than the test bars and a counter gravity chamber was designed to eliminate quality issues.

Reviewer 4:
The reviewer reported the yield was low and this was addressed by the presenter. However, there was not a strong path presented if the project team needs to increase this beyond what it has seen other than just some tuning.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer reported there is good collaboration between ANL, GM and Caterpillar.

Reviewer 2:
The reviewer said that there appear to be strong collaborations with GM, University of Iowa and ANL.

Reviewer 3:
The reviewer stated the project is teamed with GM, ANL, Iowa and Northwestern, and are also working with two foundries.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future research plan appears to be sound. A castability comparison to nodular cast iron would be of value in identifying the risk factors associated with steel casting of complex geometries the reviewer commented.

Reviewer 2:
The reviewer stated that many available options going forward were discussed and that there is a lot of space for options ahead and for post processing.

Reviewer 3:
The reviewer noted fatigue life testing seems critical to the next phase of the project.

Reviewer 4:
The reviewer observed that crankshafts are built for infinite miles and lifetime at Caterpilla . This person indicated that there is a need to find a material that can meet Caterpilla ’s and DOE’s need. The reviewer concluded the project is getting close, but not there yet.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that more accessible cast steel crankshafts will increase internal combustion engine efficienc .

Reviewer 2:
The reviewer stated that lighter weight crankshaft leads to a lighter, more efficient vehicle

Reviewer 3:
The reviewer pointed out that it is not clear how a cast crankshaft improves fuel efficiency from the current fo ged component. The project is trying to approach forged steel strengths and this would not exceed those strengths. Given that the mass is the same, there is no material decrease (no loss of weight) available, and because strength will be less, there is no gain available from decreasing the journal diameters and therefore reducing the amount of oil sheared during rotation.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that it appears that the funding has been significantly reduced and is unsure why this happened. The reviewer pointed out the reduction in the Propulsion Materials budget forced the cut in funding in this project. This person indicated it appears that the funding needed to complete this project may not be allocated, which is very concerning.

Reviewer 2:
The reviewer reported that for a project that requires both alloy development and casting process development, both the time and funding appear to be inadequate.

Reviewer 3:
The reviewer stated the project team is on target to down-select from its 14 initial alloys.

Innovative SCR Materials and Systems for Low-Temperature Aftertreatment: Yong Wang (Pacific Northwest National Laboratory) - pm066

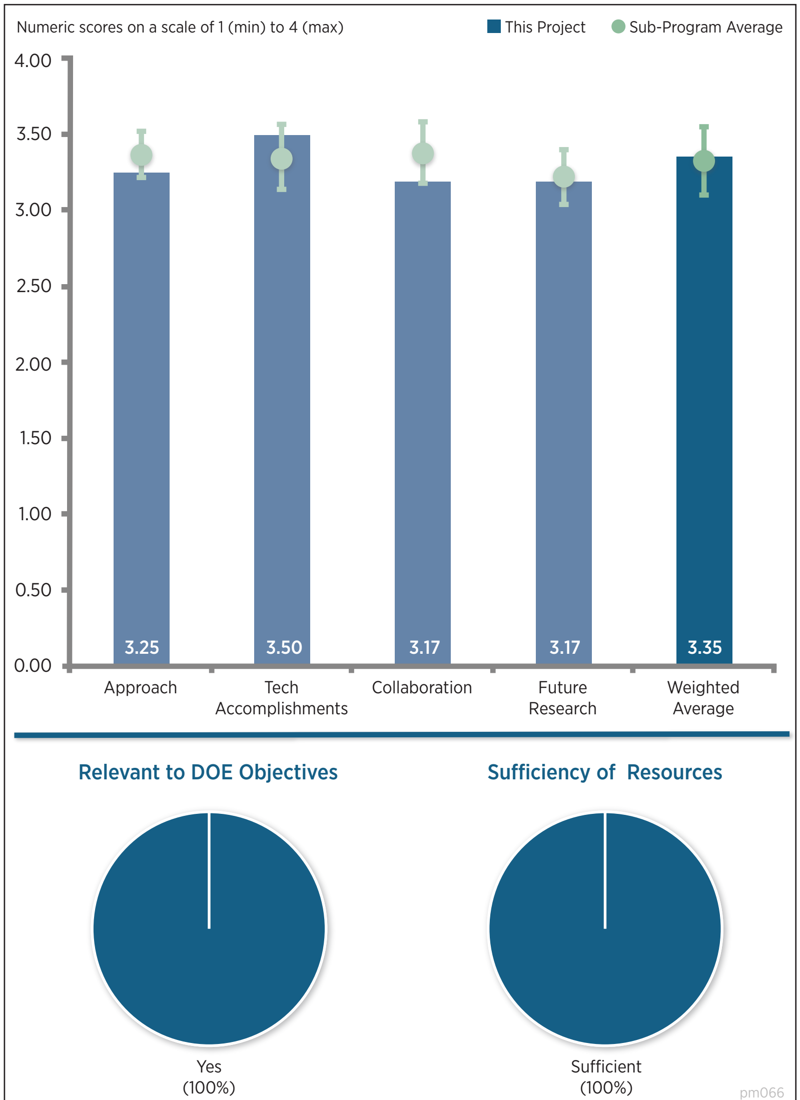

Figure 7-12 – Innovative SCR Materials and Systems for Low-Temperature Aftertreatment: Yong Wang (Pacific Northwest National Laboratory) - Propulsion Materials

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted an excellent job defining suspect elements and concentrations, as evidenced by the improvements in the first generation part. This person suggested the need to add the effect of sulfur on the new formulations.

Reviewer 2:

The reviewer commented that this project team's CRADA approach is logical and takes advantage of the expertise areas of the various partners. The project team has a logical progression of tasks that should achieve the required goals to adapt new SCR materials, develop SCR catalysts, and verify catalyst performance to meet relevant LD emission standards. The reviewer said that the approach includes work to examine costs and system impacts, which will be very important.

Reviewer 3:

The reviewer indicated that the project is aimed at cost-effective, durable, and low-temperature emissions control systems. The approach seems relatively straight-forward, focusing on development of appropriate catalyst material and then demonstrating its performance, resulting in an SCR cost model at the end. This person observed that while not included in the presentation, according to the PI, the project also plans to look at the impact of sulfur on catalyst performance.

Reviewer 4:

The reviewer pointed out that the project is focused on developing new enabling SCR catalysts with conversion efficiency necessary to meet regulations that are necessary for commercializing high-efficiency engin technologies.

Reviewer 5:

The reviewer stated the project is assessing the viability of developing a second generation SCR catalyst system. This person mentioned that low-temperature NO_x conversion performance improvement can be obtained by a two-stage process.

Reviewer 6:

The reviewer indicated that the barriers being approached do not match those in the PM area. The reviewer said that the barriers listed are from Advanced Combustion and Emission Control area and this is a PM project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the team has had a number of successes in its first year or so of work. The project team has demonstrated a first generation catalyst that achieves the required $N\ _x$ conversion efficiency at a temperature approaching the 150°C goal, which is a good initial result. This person indicated that the project team has conducted good basic science to explore ways to improve SCR catalyst activity at low temperatures. The reviewer stated that the team has demonstrated reproducible catalyst performance with multiple low-volume production batches, which is a valuable contribution to understanding how this catalyst can move to production.

Reviewer 2:

The reviewer mentioned that it is very encouraging that the project team has already decreased activation temperature significantl .

Reviewer 3:

The reviewer reported that all project milestones for late 2015 to early 2016 were achieved. So far, for the first year of the project, the project demonstrated greater than 90% conversion efficiency at 175°C, much better than current commercial systems. This person also indicated the project delivered a large batch of the first generation catalyst. From there the reviewer pointed out that the project focused on identifying a pathway to get to a second generation system. It appears that improved crystallization can improve catalyst performance. The reviewer said that the project has also down-selected a possible (ammonia [NH_3]) generation strategy.

Reviewer 4:

The reviewer observed improved current generation SCR catalysts, laying the baseline for generation two catalyst design. This person noted adding calcium (Ca) improves performance for some instances; however; Cu additions neutralize these gains, but improve lower temperature conversion. The reviewer commented that Cu additions from 1-3% are only needed to improve the NO_x conversion from 50-66% at 150°C. There was a good use of capabilities at PNNL, the reviewer reported.

Reviewer 5:

The reviewer noted that the technical accomplishments include research direction for catalyst efficiency improvement, synthesis of a large batch of first generation catalyst to identify key issues for future studies, and down-selection of a possible NH_3 generation strategy.

Reviewer 6:

The reviewer observed that the large batch of Cu/chabazite (CHA) catalyst was really a lot of combined small batches. This person questioned why a major catalyst supplier is not involved. The reviewer said that NH_3 generation catalyst details were not described.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the project is a collaboration between FCA and PNNL, with assistance from the University of Houston (UH). FCA (with the help of UH) will focus on passive NH_3 generation and system integration, along with supplemental NO_x control. PNNL will focus primarily on low-temperature SCR development, along with system integration. The reviewer pointed out that this is a relatively small team, but appears to have the key members needed. The reviewer noted that there is a strong degree of communication among the members, including monthly conference calls along with face-to-face meetings every six months.

Reviewer 2:

The reviewer said that the project team includes a good combination of OEM, laboratory, and university collaboration with good communication and noted this team has a good balance of technical expertise relevant to the work to be completed.

Reviewer 3:

The reviewer indicated there is good collaboration and includes the right team.

Reviewer 4:

The reviewer acknowledged that there is appropriate collaboration among project partners leveraging their core competencies and include: PNNL (catalyst development and advanced characterizations), FCA (system integration and operational parameters), and UH (catalyst characterization, degradation, and modeling).

Reviewer 5:

The reviewer commented that the partners included an OEM, national laboratory, and university, and that collaboration level seems adequate.

Reviewer 6:

The reviewer noted that national laboratory, industry and academia are all participating in this project. This person suggested that the project could use an aftertreatment firm that specializes in SCR systems to complement the team and that a HD vehicle manufacturer could also add some insight into issues and possible solutions.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said the project has appropriate future work focusing on development of second-generation catalysts to improve efficienc , stability and aging.

Reviewer 2:

The reviewer indicated that the future work is appropriate and is logical for achieving the goals of the project.

Reviewer 3:

The reviewer noted a good path forward to continue the gains that they have already realized.

Reviewer 4:

The reviewer observed that the project includes several very specific plans for future research, and include development of the second generation catalysts and verifying their performance stability, designing the NH_3 generation system, and conducting system component aging.

Reviewer 5:

The reviewer pointed out future work will include development of a second generation SCR catalyst to meet the conversion efficiency ta get, which is a primary goal; verifying sufficient hydrothermal stability of second generation SCR catalysts; designing an NH_3 generation strategy; and performing system component aging. This person indicated that all of these activities will be needed to resolve the issues currently preventing the development of a low-temperature NO_x conversion system.

Reviewer 6:

The reviewer stated that washcoat loading of SCR catalysts is very important but was not mentioned in future work slide. In addition, this person pointed out that it was not clear if the NH_3 generation catalyst would also be scaled up to a core level.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer observed that this project supports the DOE petroleum displacement objective by developing emissions aftertreatment solution to enable high efficiency engines. Specifical , the project is addressing the 150°C Challenge identified in the 2012 USCAR workshop

Reviewer 2:
The reviewer said yes, lower temperature aftertreatment capability supports DOE's goals of higher fuel efficienc .

Reviewer 3:
The reviewer stated yes, the ability to limit or remove thermal management would create a significant improvement in fuel economy.

Reviewer 4:
The reviewer indicated that the project is specifically aimed at addressing the 150°C Challenge identified at th 2012 USCAR workshop. As such, this project is trying to ensure high (90%) conversion efficiency SCR catalyst systems at a low temperature (150°C), which are anticipated to be needed by advanced technology powertrains.

Reviewer 5:
The reviewer noted that improved SCR materials can enable meeting stringent emission standards with more efficient catalysts and facilitate new more efficient powertrains This in turn creates the opportunity for petroleum reduction.

Reviewer 6:
The reviewer indicated that higher SCR conversion efficiency will reduce fuel and aftertreatment fluid us

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the resources are sufficient to complete the work as described in the presentation

Reviewer 2:
This person indicated that funding appears appropriate for this project.

Reviewer 3:
The reviewer stated that no indication was made that the funding was insufficient

Reviewer 4:
The reviewer pointed out that the project funding of $500,000 per year over a three-year period seems appropriate given the project scope.

Reviewer 5:
The reviewer noted the project team seems to be on track and meeting their milestones.

Reviewer 6:
The reviewer observed that it was not clear how much funding PNNL and UH were each receiving.

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Next Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines: Christine Lambert (Ford Motor Company) - pm067

Presenter

Christine Lambert, Ford

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

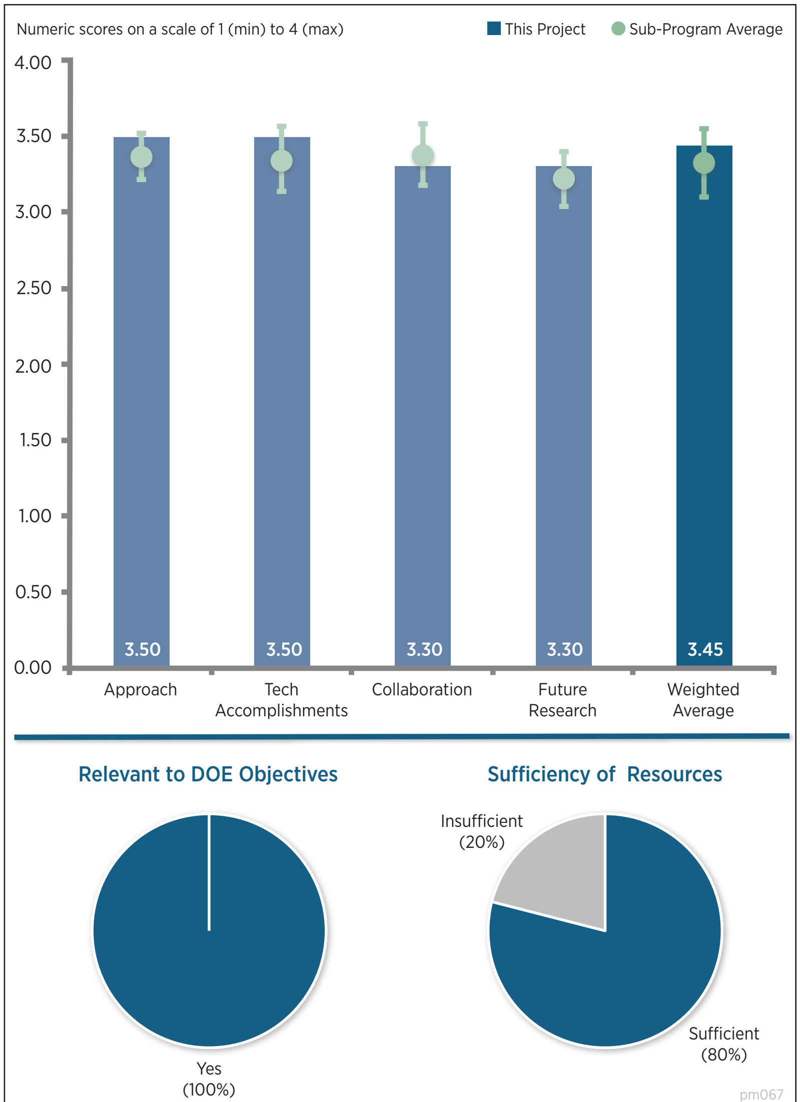

Figure 7-13 – Next Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines: Christine Lambert (Ford Motor Company) - Propulsion Materials

Reviewer 1:

The reviewer observed this is an excellent approach to investigating new catalyst materials and options including identifying and characterizing new materials and predicting performance and costs. In addition, the project will identify and capitalize on synergies between various catalyst materials within and between partners, increase surface area but not increasing the content of metals, investigate catalyst architectures containing a core shell conformation composed of a metal nanoparticle surrounded by a metal oxide shell, and where appropriate, use ICME to help with material development activities.

Reviewer 2:

The reviewer noted that the project's approach appears straightforward, and there is a rational path of activities to accomplish its objectives. The project is looking at new ways of characterizing innovative materials and catalyst designs, rather than simply increasing the content of precious metals. The reviewer further explained that this would drive up cost, although some comparisons were run by increasing these materials. These include oxide overlayers and improved mixing. A specific component of the approach is also to leverage the partners analytical capabilities. The reviewer observed that at this time, the testing is being done using Iso-octane, not 10% ethanol blend with gasoline (E10), which represents probably 95% of the commonly-available gasoline at refueling stations. Upon questioning, the PI indicated future efforts may consider this. The reviewer commented the specific fuel formulation could impact catalyst design.

Reviewer 3:

The reviewer stated that the technical approach is logical, and will push three-way catalyst technology forward by looking at catalyst fundamentals. The team is exploring novel approaches for catalyst materials to improve catalyst activity. It is good to see Ford's focus on cost estimation for these new materials. The reviewer mentioned that this is very important, particularly for a relatively mature technology like the three-way catalyst that is produced at high volume and low cost.

Reviewer 4:

The reviewer said predictive capabilities are being utilized in tandem with characterization techniques. The reviewer suggested that the multiple approaches presented offer a better chance of success and it is good that the project can run these in parallel.

Reviewer 5:

The reviewer noted that this work directly addresses the request for expanded efforts of low-temperature aftertreatment resulting from USCAR engine and aftertreatment workshops and roadmaps. As such and in recognition of global drive cycles experiencing temperatures in the 150°C range, developing catalyst solutions for low-temperature oxidation of carbon monoxide (CO) and HC species for three-way catalyst (TWC) applications is very appropriate and supported research. The inception stage exploration of multiple pathways to achieve high CO and HC oxidation performance and reduced metal cost at low temperature through maintaining highly dispersed Pt- group metal (PGM) is a viable strategy to achieve the desired performance of catalysts. However, maintaining this functionality after experiencing real aging conditions (thermal and poisons) is essential to the adoption of any of these technologies. The reviewer suggested that a better understanding of how poisons, such as sulfur, alter the activity of the catalysts under development is needed to provide a thorough characterization of the technologies.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer agreed that beginning a study by baseline reactors that will be used to judge the performance of the various catalysts is the proper way to begin. Using the protocols developed by USCAR adds an additional layer of confidence to the results. This person noted that, the light-off performance of the palladium (Pd) versus rhodium (Rh) formulations is somewhat unexpected, but interesting. The fresh CO light-off performance of the fresh Rh formulation is unexpected. The reviewer suggested that because most catalyst formulation use a combination of Pd and Rh, it would be of interest to determine how the resulting light-off performance would illuminate the interaction between the metals. This person also asked if Rh will also be compared on the titanium dioxide (TiO_2) support. The reviewer explained that Pd suffers more from sulfur poisoning and that light-off data may also change the ranking of the different formulations. The reviewer noted that with respect to the silicon dioxide (SiO_2) core catalyst, spectroscopically comparing the fresh to the aged sample would be of interest. In general, the effect of sulfur at low temperature on the light-off performance of the well dispersed Pd catalysts is needed. In all cases, determining the selectivity of the NO_x species toward nitrous oxide (N_2O) formation should be assessed for greenhouse gas (GHG) inventory estimates. However, the reviewer observed overall the data support encouraging oxidation performance at temperatures approaching the goal of 150°C.

Reviewer 2:

The reviewer indicated that the project team’s systematic work starts with the basics of laboratory reactor performance confirmation, which is an important step. The team has done quite a bit of good scientific work on catalyst materials development in the first half of this project. The reviewer observed that the project team has not yet quite gotten to the 150°C temperature goal, but has shown some promising catalyst materials that are moving in that direction. The core shell catalyst material and its associated synthesis process are interesting, said the reviewer. The team is focusing on making its own materials, versus sourcing black box materials from suppliers, to understand how they work and can be used is a good approach. This person mentioned that this project has shown great early results and it appears there are more to come.

Reviewer 3:

The reviewer observed that the round robin for commercial catalysts is complete, but took longer than anticipated. There was good agreement on results among the three research laboratories including Ford, ORNL and the UM. The reviewer pointed out that the project team learned a great deal about performance of various catalyst formulations as well as the impact of aging.

Reviewer 4:

The reviewer reported that round robin testing is completed and investigated production catalysts first, the Rh contribution gets close to 150°C after 950°C, lean aging, and that titanium worked well. In addition, this person pointed out the Rh in four mode aging at 960°C was best performer and that Rh has good promise as an addition to the catalyst material. The reviewer said that 4% Pd also looks like a good potential element to add from tests. Multiple catalysts to address each pollutant could be an option, ternary base metal oxides has significant CO reduction and can store NO_x at low temperatures; however, it has little effect on the others. The reviewer also noted that dispersed Pd improved catalyst light-off.

Reviewer 5:

The reviewer noted that low-temperature light-off changes are promising for improved efficienc , and less thermal management.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the partnering in this project is appropriate for the scope of the project and the background of the groups involved.

Reviewer 2:

Three participants, Ford, ORNL, and UM, were characterized as equal contributors to the project by the presenter. This person pointed out that adding a coater would be a positive. It would be disappointing if the project team developed a material that could not be applied in a consistent way in production.

Reviewer 3:

The reviewer stated that the project includes Ford, ONRL, and UM. All three are considered as contributing equally under the project, with specifically identified tasking This person pointed out that monthly calls are held among the partners, along with in-person meetings once or twice per year. The reviewer noted that the project will partner with a catalyst supplier in the third year of the project.

Reviewer 4:

The reviewer remarked that Ford and ORNL are partners and are leveraging their core capabilities for this work. The team has a good mix of OEM, laboratory, and university partners. The team is looking to add a catalyst supplier in the third year, which will be a critical step. The reviewer observed that is good to develop and understand your own materials, but a catalyst supplier can provide additional insight.

Reviewer 5:

The reviewer acknowledged that academic, industry and national laboratory partnerships are in place, and that adding a Tier 1 powder supplier would help. In addition, the year three addition of catalyst manufacturer will also improve team capabilities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the team has good plans to address the remaining barriers, particularly lead times and costs for materials. The system-level work should be interesting and add to the community's knowledge, noted the reviewer.

Reviewer 2:

The reviewer noted that the future work to address remaining questions and fill the knowledge gaps is appropriate

Reviewer 3:

The reviewer observed that several specific future activities were proposed. In particula , the third year of the project calls for combining novel materials into a complete catalyst and then partnering with a major automotive catalyst supplier. Other future efforts include activities focused on shortening materials commercialization lead-times and reducing costs, culminating in identifying systems solutions and estimating vehicle performance and cost, the reviewer reported.

Reviewer 4:
The reviewer suggested that the novel materials should be a parallel path rather than waiting until the third year to add them to the project because if the project team has issues, there are not sufficient resources left to recover and meet deliverables.

Reviewer 5:
This reviewer provided the following comments: long lead time in materials commercialization; add new materials to base to understand catalyst materials; investigate base metals as a PGM substitute to reduce cost; capitalize on catalyst material synergies to develop an emission solution/system; develop cost estimate of new system; and demonstrate full aging and performance of coated monolith cores. The reviewer suggested that a good additional activity would be developing a functional, prototype catalyst system using the most promising materials and configuration

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer pointed out that the project is focused on developing improved catalysts for high-efficiency engines, including addressing long lead times for materials commercialization and cost. Because next generation engines are anticipated to have lower exhaust temperatures, the project is aiming at improving catalyst performance at lower temperatures through materials selection. This person stated that this is highly relevant to DOE VTO objectives.

Reviewer 2:
The reviewer commented that this project supports USCAR and U.S. Driving Research and Innovation for Vehicle Efficiency and Ene gy sustainability (U.S. DRIVE) initiatives to address the need for effective low-temperature aftertreatment solutions for highly efficient engines. This work also supports the need for cost effective emissions control.

Reviewer 3:
The reviewer said that removal of thermal management is a big win and it would be good to add a calculation relating the impact of meeting the goals on the effect of petroleum displacement.

Reviewer 4:
The reviewer indicated that low-temperature catalysis is important for future advanced combustion engine technologies to reduce fuel consumption. More thermally efficient engines will have lower exhaust temperatures, but still be required to meet criteria emission standards. Lower temperature catalysts are thus critical enablers for these efficient engines, the reviewer remarked

Reviewer 5:
The reviewer mentioned that higher efficiency conversion of emissions can allow more efficient, lower temperatur combustion techniques.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that with the anticipated near-term commercialization of advanced lower temperature combustion engines, this critical need will require a solution to be developed to meet current and future emission regulations. This person suggested an increase in funding would accelerate completion of the project milestones.

Reviewer 2:
The reviewer explained that no indication was made that the funds were insufficient, so the reviewer were assumed

to be fine. It should be noted that there is only a 20% cost-share on this project. The reviewer observed that given the higher levels of cost-share on related projects within PM, this appears a bit unusual.

Reviewer 3:

The reviewer stated that this project is appropriately funded and staffed.

Reviewer 4:

The reviewer said the project is on track and meeting milestones.

Reviewer 5:

The reviewer indicated that resources appear to be sufficient to address the work described

Sustained Low-Temperature NO_x Reduction (SLTNR): Yuhui Zha (Cummins) - pm068

Presenter

Yuhui Zha, Cummins

Reviewer Sample Size

A total of four reviewers evaluated this project.

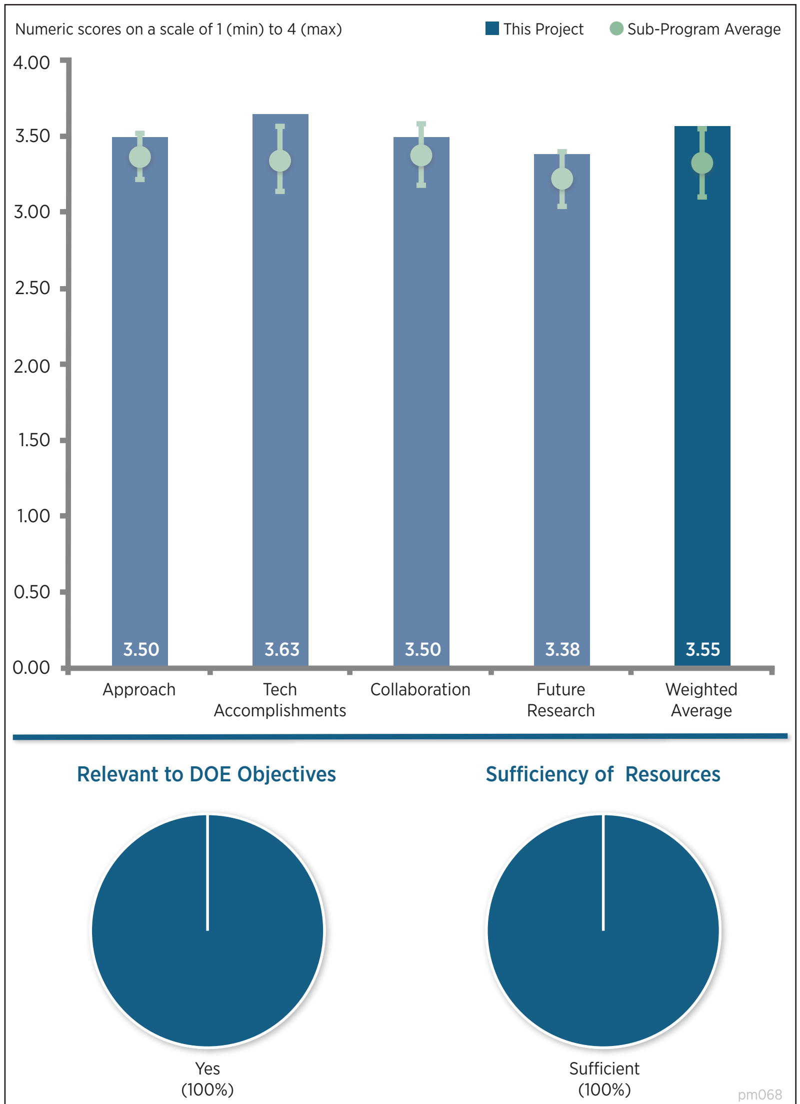

Figure 7-14 – Sustained Low-Temperature NO_x Reduction (SLTNR): Yuhui Zha (Cummins) - Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer pointed out that the approach as outlined is logical and addresses the key technical points for low-temperature NO_x reduction with a systems approach. The approach addresses the commercial viability of the system, which is very useful to move this to implementation. This person stated that the on-engine test verification of the catalyst system is even more important for implementation. Including the reductant system is essential, as there are well-known challenges with low-temperature deposit formation with current reductant dosing systems. The reviewer reported that the project team is making good use of partner core capabilities through the extensive catalyst expertise at PNNL.

Reviewer 2:

The reviewer stated this is a nice balanced approach between system development and modeling approach to enhance catalyst performance. The PI is using a creative, outside-the-box approach to emission control by considering alternative positions and locations for emission control systems. This solution will require a redesign of the emission control system. This person suggested that opportunities exist to utilize the pre-turbo exhaust temperatures of 230°C to improve pollutant conversion. However, there is limited space in/near the engine for a conventional solution. The reviewer mentioned that a vaporizer is being tested to delivery diesel exhaust fluid to the exhaust stream in this area.

Reviewer 3:

The reviewer observed that the project's approach seems to be reasonable for accomplishing the identified objectives of developing an appropriate catalyst system, conducting on-engine testing to verify performance, and conducting a commercial viability assessment. A number of discrete steps (milestones) were identified for the project, which assists greatly in tracking project progress, the reviewer said.

Reviewer 4:
The reviewer indicated this is a sound approach focusing on DOC, SCR, and reductant delivery systems as well as modeling to size catalysts and optimize design.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer reported that the team has made very good progress on completing its technical milestones. PNNL's work in identifying the critical low-temperature SCR characteristics and developing promising catalysts to take advantage of this work represents a significant accomplishment. The proposed pre-turbo catalyst design is interesting, but ensures access to heat for proper catalyst operation. This person observed that the project team has completed a good comprehensive modeling study of concept designs to look at catalyst location and sizing. The vaporizer for SCR dosing is also interesting, particularly as it takes advantage of something that appeared unrelated to SCR dosing (a commercial humidifier). The reviewer pointed out that challenges remain for this system, but initial results are promising. The reviewer said that the team is also making good progress on commercial viability with the initial framework and key technical and market considerations.

Reviewer 2:
The reviewer noted that all calendar year 2015 milestones were completed. Initial results are that ammonium nitrate formation is a key inhibitor, so its decomposition must be promoted catalytically through material changes and pore structure design. Adding iron/zeolite helps conversion performance. In addition, HC also inhibit low-temperature nitric oxide oxidation, and both HC and nitrogen dioxide (NO_2) are dependent upon exhaust gas recirculation (EGR) fraction, which tends to be set to maximize diesel oxidation catalyst performance. The reviewer observed that it appears if the EGR fraction is 0.4, the team can reach the desired NO_x conversion at 210°-230°C (which is a pre-turbo temperature, but somewhat higher than the goal of 150°C). PNNL has already developed a catalyst formulation that appears to achieve greater than 90% NO_x conversion at 150°C under laboratory conditions, and Johnson Matthey has successfully scaled this material up to a monolith sample.

Reviewer 3:
The reviewer stated that accomplishments include SCR development and design, integrated high NO_2 strategy, as well as modeling and vaporizer design. This person noted that commercial viability assessment was also started.

Reviewer 4:
The reviewer indicated that all milestones are on schedule. The Fe/zeolite formulation can achieve 90% NO_x conversion at 150°C, said the reviewer. This person pointed out there is continuing modeling analysis with Cu/Zeolite to determine optimized system sizing. In addition, the Fe plus Cu components together reduces sensitivities to NO_2 fractions and Cu needs to be seven to eight times greater than the Fe component. The reviewer commented that two good options were identified up to 230°C (i.e., low- to mid-cost, and mid- to low-size). Proof of concept illustrated that there is limited space for catalyst pre- or post-turbo. The reviewer noted that the vaporizer creates 10 times smaller size particles than dosers, and that the project is using off-the-shelf components in vaporizer design, except for housings. The project completed a prototype in June 2016. The reviewer suggested assessing risk factors to determine commercial viability.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated that the project is a collaboration between Cummins, PNNL, and Johnson Matthey. Each appears to have critical roles under the project. While it is perhaps a small team, the partners appear to cover the project's needs at this time and are working together well.

Reviewer 2:
The reviewer stated that it seems like very close collaboration among Cummins, PNNL and Johnson Matthey leveraging their aftertreatment system development, modeling, and catalyst design expertise, respectively.

Reviewer 3:
The reviewer acknowledged that the team has an appropriate mix of partners, with an engine OEM, a catalyst supplier, and a national laboratory. The team has balanced the work among the partners in ways appropriate to each partner's core competencies.

Reviewer 4:
The reviewer noted that industry, emission control Tier 1 supplier, and a national laboratory are partnering on this project. The reviewer suggested an academic institution should be considered as an addition to the team.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the future work plan appears to be logical and appropriate for finalizing and testing the low-temperature NO_x catalysts and reductant system. It was not mentioned in the presentation, but it is presumed that the engine testing of the full SCR system will be in 2017, which appears appropriate.

Reviewer 2:
The reviewer reported that a number of future activities were identified, but the key ones were to test catalyst durability and robustness and develop and integrate the urea vaporizer system. In addition, next steps were identified as fabrication and insulation, and then engine testing

Reviewer 3:
The reviewer indicated that future tasks include optimizing the SCR system, completing the integrated high NO_2 strategy, and designing, building, and testing the reductant delivery system.

Reviewer 4:
The reviewer explained that durability, robustness of performance in operating conditions still needs to be shown and the project will develop an integrated high NO_2 strategy. Three SCR designs are to be assessed in 2016. The reviewer noted there is a need to complete a proof a concept design for reductant delivery system and to complete CFD analysis, bench testing, system integration and engine tests, which are all planned for 2016.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer observed that the project is focused on ensuring highly-efficient N $_x$ conversion at the low temperatures that may be more likely to characterize advanced higher efficiency engines. Thus, this is entirely relevant to DOE/VTO objectives.

Reviewer 2:
The reviewer emphasized that this project supports the overall DOE objectives of petroleum displacement by enabling high-efficiency medium and HD diesel engines that meet emissions requirements. More efficient engine have lower exhaust temperatures which create very challenging conditions for exhaust aftertreatment. This person concluded that this project directly addresses the low exhaust temperature performance of the SCR system.

Reviewer 3:
The reviewer explained that low-temperature NO_x reduction will be important for future HD efficiency applications. In addition, higher efficiency will mean lower exhaust temperatures, and manufacturers will need to meet criteria emission regulations at these conditions. This person pointed out that more efficient emission controls at the conditions presented by future high brake thermal efficiency engines are a necessary enabler for deployment of these engines and resulting petroleum displacement.

Reviewer 4:

The reviewer stated that high efficiency emission control can reduce the need for frequent DPF regeneration, which uses a significant amount of fuel

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that no indication was made that the funding was either excessive or insufficient, so it was assumed to be appropriate. Overall funding appears to include a 40% cost-share from Cummins.

Reviewer 2:

The reviewer said that the approximate $3 million total budget ($2 million DOE share) seems appropriate for a three-year project scope.

Reviewer 3:

The reviewer indicated that the resources appear to be sufficient for the work described, over the timeframe proposed.

Reviewer 4:

The reviewer indicated the review was considered as a phase one project, and as such the funding appears to be sufficient. This person suggested that risk factors need to be assessed to determine follow on work towards a commercial solution, especially regarding the vaporizer.

Acronyms and Abbreviations

3D	Three-dimensional
Al	Aluminum
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APS	Advanced photon source
ASTM	American Society of Testing and Materials
°C	Degrees Celsius (Centigrade)
Ca	Calcium
CFD	Computational fluid dynamics
CGI	Compacted graphite iron
CHA	Chabazite
CHT	Conjugate heat transfer
CO	Carbon Monoxide
CRADA	Cooperative research and development agreement
Cu	Copper
DFT	Density functional theory
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	Diesel particulate filte
Dy	Dysprosium
E10	10% Ethanol Blended with Gasoline
EDT	Electric Drive Technologies
EGR	Exhaust gas recirculation
EV	Electric vehicle
FCA	Fiat Chrysler Automobiles
Fe	Iron
FEM	Finite element modeling
FSW	Friction-stir welding
FY	Fiscal year
GHG	Greenhouse gas

GM	General Motors
GT	Georgia Tech University
GTDI	Gasoline turbocharged direct injection
HC	Hydrocarbon
HD	Heavy-duty
HDV	Heavy-duty vehicle
HPDC	High-pressure diecast
HEV	Hybrid electric vehicle
Hp	Horsepower
ICME	Integrated computational materials engineering
IP	Intellectual property
IPM	Interior permanent magnet
K	Potassium
L	Liter
LD	Light-duty
Mg	Magnesium
MGI	Materials Genome Initiative
MPG	Miles per gallon
MIT	Massachusetts Institute of Technology
MPa	Megapascal
N_2O	Nitrous Oxide
Na	Sodium
Nd	Neodymium
NH_3	Ammonia
Ni	Nickel
N_2O	Nitrous oxide
NO_2	Nitrogen Dioxide
NO_x	Oxides of nitrogen
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
OQMD	Open Quantum Materials Database

ORNL	Oak Ridge National Laboratory
Pd	Palladium
PGM	Platinum group metal
PI	Principal Investigator
PM	Propulsion Materials
PNNL	Pacific Northwest National Laborator
Pt	Platinum
R&D	Research and development
Rh	Rhodium
RTA	Rio Tinto Alcan
SCR	Selective catalytic reduction
SI	Spark ignition
SiO_2	Silicon dioxide
TEM	Transmission electron microscope
TiO_2	Titanium dioxide
TMS	The Materials, Metals and Minerals Society
TRL	Technology readiness levels
TWC	Three-way catalyst
USAMP	United States Automotive Materials Partnership
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle efficiency and Ene gy sustainability
UAB	University of Alabama at Birmingham
UH	University of Houston
UM	University of Michigan
USCAR	United States Council for Automotive Research
UTS	Ultimate tensile strength
VACG	Vacuum assisted counter gravity
VTO	Vehicle Technologies Offic